West Virginia University
Forensic Science Initiative, Research Office
College of Business & Economics

FORESIGHT

Executive Summary 2007/2008

A business approach to improving forensic science services

Executive Summary[1]

FORESIGHT: A business approach to improving forensic services

Managers of scientific laboratories see themselves as scientists first and managers second; consequently, they tend to devalue the managerial aspects of their jobs[2]. Forensic laboratory managers are no different but the stakes may be much higher given the importance of quality science to the criminal justice system. The need for training and support in forensic laboratory management has been recognized for many years but little has been done to transition the tools of business to the forensic laboratory environment.

Benchmarking is improving performance by recognizing, understanding, and integrating best—or at least better—practices from either inside the organization or from outside entities. To move forward on a benchmarking project, a standard of comparison must be established. Currently in forensic science, no such standard exists. FORESIGHT codified the standard metrics to collect and these provide the basis for broad yet deep comparisons between forensic laboratories. **FORESIGHT is open to any forensic laboratory that completes and submits a LabRAT form** (website URL).

QUADRUPOL

A study in Europe, called Quadrupol[3], did an in-depth analysis of 4 forensic laboratories in the European Union, namely Sweden, Netherlands, Poland, and Finland. At the 2006 International Forensic Business and Economics Colloquium sponsored by the West Virginia University Forensic Science Initiative, it was decided that a similar study would benefit North American forensic laboratories.

FORESIGHT

FORESIGHT is a business-guided self-evaluation of forensic science laboratories across North America. The participating laboratories represent local, regional, state, and federal agencies. Faculty from the WVU College of Business and Economics provided assistance, guidance, and analysis. The process involved standardizing definitions for metrics to evaluate work processes, linking financial information to work tasks and functions. Laboratory managers can use these functions to assess resource allocations, efficiencies, and value of services—the mission is to measure, preserve what works, and change what does not. While the *Census of Public Crime Laboratories*[4] and the

[1] This project is being conducted with support from the National Institute of Justice (Award 2003-RC-CX-K001)
[2] Geles C, Lindecker G, Month M, Roche C. *Managing Science*. New York: John Wiley & Sons, 2000.
[3] Unpublished report of the European Network of Forensic Science Institutes.
[4] Available on-line at http://www.ncjrs.gov/app/publications/abstract.aspx?ID=207205.

International Association for Identification Forensic Service Providers Survey[5] approach the forensic industry broadly, FORESIGHT shows processes, strategies, resources, and allocations at a detailed level. Definitions were kept as similar as possible to the Quadrupol study to promote collaboration; Appendix A contains the glossary for FORESIGHT definitions and Appendix B contains the investigative area definitions for the project. Differences in human resource and management structure made some topics unrelated or irrelevant, while others had to be redefined for use in North America.

A project of this magnitude for forensic laboratories has not been carried out anywhere. It is hoped that international cooperation will improve forensic laboratory performance and increase the quality and efficiency of their services to their respective justice systems.

The FORESIGHT laboratories participated on a volunteer basis, with costs for travel and analysis covered through a cooperative agreement with the National Institute of Justice (NIJ). In agreement with the laboratories and NIJ, only the laboratories performing in the upper quartile of a metric would be identified: The goal of FORESIGHT is improvement, not punishment. Laboratories not in the upper quartile were self-aware of their results and performance relative to the other laboratories. The laboratories in the upper quartile then represented a "better practice" contact to discuss what processes may have led to that performance.

Methodology[6]

While forensic laboratories have similar missions, differences such as populations served, geographic coverage, jurisdiction, legislative mandates, breadth of investigative areas, staffing, and existing facilities make direct comparisons of productivity across laboratories difficult. Adjustments for resources and responsibilities through the creation of ratios can produce meaningful metrics across a range of laboratories. Ratios provide *relative* measures that make for easier comparisons across disparate operational entities. Ratios permit a laboratory to measure their performance over time, against specific other laboratory operations, and against industry (averages) standards. The ability of a laboratory to assess performance over time permits management to relate performance to changes in either scientific advancement or managerial prowess, for example.

There is a seemingly endless array of potential metrics that might be devised from the data in any crime laboratory. In the analysis that follows, some possible ratios are discussed, but the list is not exhaustive. Individual laboratories will likely have other items that are of particular interest to the management team, the lab director or to those with oversight responsibilities. For discussion purposes, the ratios are broken down into five categories: Efficiency, Quality or Risk Management, Analytical Process, Market Conditions and Return on Investment.

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[5] Childs, R. et al., "A Survey of Forensic Science Service Providers," *Forensic Science Policy and Management*, in press, 2009.

[6] This section contains material from Speaker, P.J. "Key Performance Indicators and Managerial Analysis for Crime Laboratories," *Forensic Science Policy and Management*, in press, 2009.

The ratios used are collected through the Laboratory Reporting and Analysis Tool (LabRAT). LabRAT is a condensed, active data collection tool that allows for easy entry of information most forensic laboratory directors should have or be able to get readily (Appendix C shows the LabRAT form). The actual LabRAT forms are available in spreadsheet format; the forms in Appendix C are for display. Examples of how to assess Items, Sample, and Tests are shown in Appendix D.

Cautions and Caveats

Crime laboratories routinely generate data from casework performance across investigative areas, personnel and budget allocations and corresponding expenses. This paper considers ways in which laboratories can make data driven managerial decisions through the regular extraction of data to create key performance indicators. The techniques borrow from the experience in other industries and are modified for the specific needs of crime laboratories.

From accounting, we learn how common size financial statements can be easily created to transform the "financial statements" of individual laboratories into size-adjusted analytical tools that can be easily compared against peer labs and industry standards. From business finance, we learn that transforming absolute dollar performance measures into size-adjusted ratios permits an evaluation of the allocation of resources into measures of efficiency, quality/risk management, analytical process choices, market conditions, and return on investment.

These key performance indicators can then be compared to peer laboratory performance and/or be used to determine in-house trends for the proper management of the scarce resources at its disposal or to provide quantitative support for the acquisition of additional resources. As the leading organizations in the industry begin to assess and adopt a common set of measures through the determination of industry-wide standards for data collection, then the stories may be told by the leaders in the industry in an effort to identify best practices. Dissemination of those success stories and adoption of similar practices offers a winning opportunity for all.

Some cautionary tales must also be borrowed from the application of these measures in other industries. It is a natural tendency to lose sight of the organizational goals and begin to manage (i.e., influence) the measures. Remember that the ratios serve to proxy performance in the individual areas of concern. ***No single ratio should be evaluated in isolation. There is a natural temptation to play to the measures and lose sight of the goals.*** For example, with a goal of a lower cost per case, one way for crime lab managers to improve the metric is to assume more risk, for example, reducing quality assurance activities. But, that risk may prove dangerous and even devastating in the long-run. "Accountability should be for results and for due process. Too many numbers and you

drive out judgment."[7] The metrics themselves are not the answers but are pointers to the processes which are the answers to questions of improved performance.

Implementation of the ratios into the management process can be tremendously beneficial to laboratories. But, stakeholders must be reminded to maintain the balance between return, risk, and efficiency to achieve the organizational goals and avoid the pitfalls that have confronted other industries.

Overview of 2007-2008 Results

The 14 forensic laboratories participating in FORESIGHT have the following jurisdictions:

- 5 local agencies[8]
- 8 state agencies
- One national

The average FORESIGHT forensic laboratory in this study has the following characteristics:

	Mean	Median
Total Personnel (FTEs)	132	105
Budget (in millions)	$13.71	$12.44
Cases submitted	35,737	26,102
Backlogged cases (>30 days)	6,365	1,755
Jurisdiction (in millions)	4.8	3.6

Efficiency Measures

A variety of efficiency measures are available to evaluate efficiency including:

Cases/FTE = Area Cases Processed/Full-time Equivalent Employees

Samples/FTE = Samples Process/ Full-time Equivalent Employees

Tests/FTE = Tests Completed/ Full-time Equivalent Employees

[7] Henry Mintzberg, as quoted in Pakalnis V. Canada's Management Guru. *Canadian Government Executive*. 2007;January:6-8.

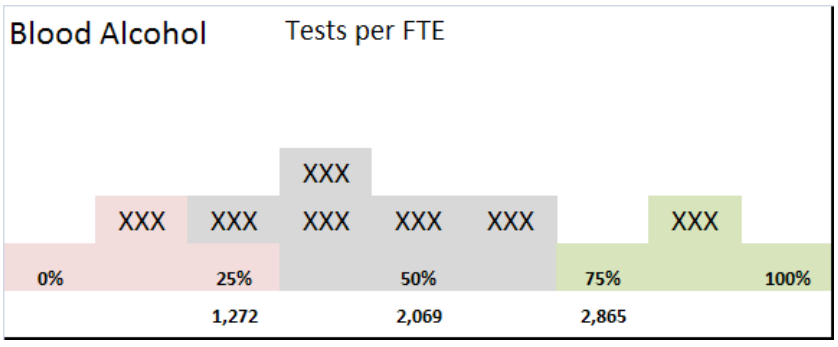
[8] "Local" includes city, county, and regional jurisdictions.

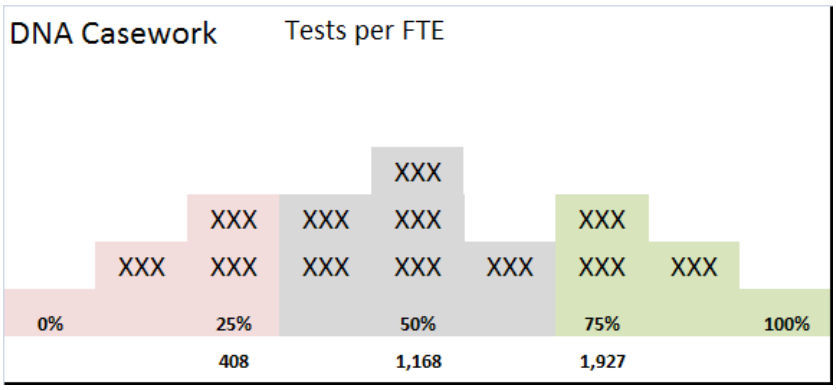
The average value for the lowest level of detail of these measures by investigative area is presented in Table 1. The coefficient of variation (CV) is an excellent measure for this analysis because both return and risk are variables of interest. Because the CV is not a linear relationship, it is the most appropriate measure to present relative risk. For anything where higher return on investment (ROI) and lower risk are desired, the ratio of the two is a very good measure. Those investigative areas with a high coefficient of variation are the areas with the greatest potential gains from a view of best practices.

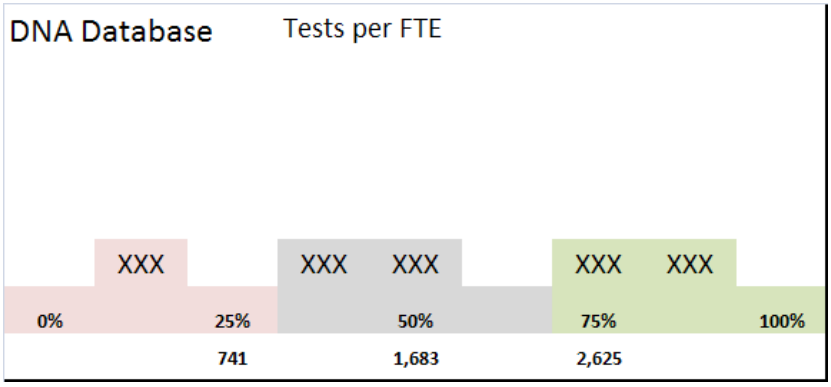
Investigation area	Mean	Standard Deviation	CV
Blood Alcohol	3,696	4,419	1.20
Computer Analysis	335	400	1.19
Crime Scene Investigation	11,195	13,456	1.20
Digital evidence	13,150	22,504	1.71
DNA Casework	1,648	2,021	1.23
DNA Database	3,048	3,531	1.16
Document Examination	643	702	1.09
Drugs/Controlled Substances	7,522	9,507	1.26
Evidence Screening & Processing	1,509	1,559	1.03
Environmental analysis	6,064	8,112	1.34
Explosives	897	1,224	1.36
Fingerprints	13,423	33,369	2.49
Fire analysis	852	676	0.79
Firearms and Ballistics	1,718	1,388	0.81
Gun Shot Residue (GSR)	2,637	4,543	1.72
Hairs & Fibers	5,443	12,766	2.35
Handwriting	1,794	3,002	1.67
Marks and Impressions	1,915	3,477	1.82
Paint & Glass	1,514	1,481	0.98
Serology/Biology	6,455	9,549	1.48
Toxicology ante mortem (excluding BAC)	1,791	2,740	1.53
Toxicology post mortem (excluding BAC)	626	454	0.73
Trace Evidence	2,785	6,320	2.27

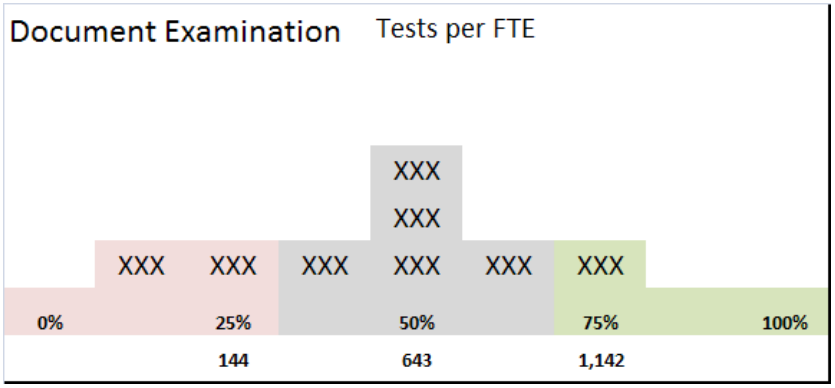
Table 1—TEST/FTE (Labor Productivity)

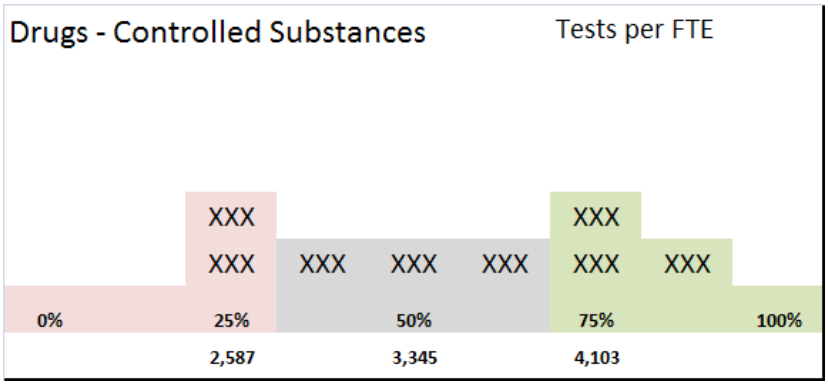
The distribution of this efficiency measure by selected investigative area is presented in the following schematics. In each of these efficiency distributions, the quartiles and the quartile values are presented. Each participating forensic laboratory is presented anonymously. Those laboratories in the highest quartile are highlighted in green and those in the lowest quartile are highlighted in red.

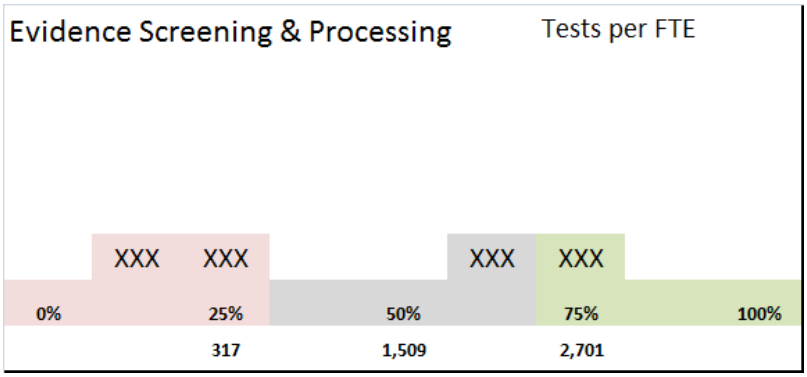


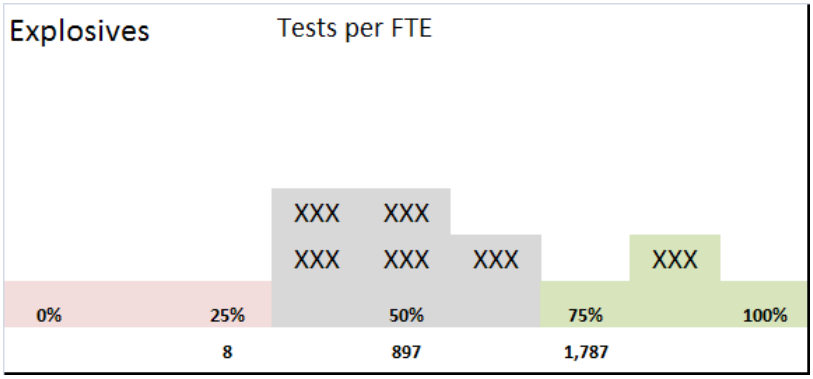

DNA Casework
Tests per FTE
XXX
XXX XXX XXX XXX XXX
XXX XXX XXX XXX XXX XXX XXX
0%
25%
50%
75%
100%
408
1,168
1,927

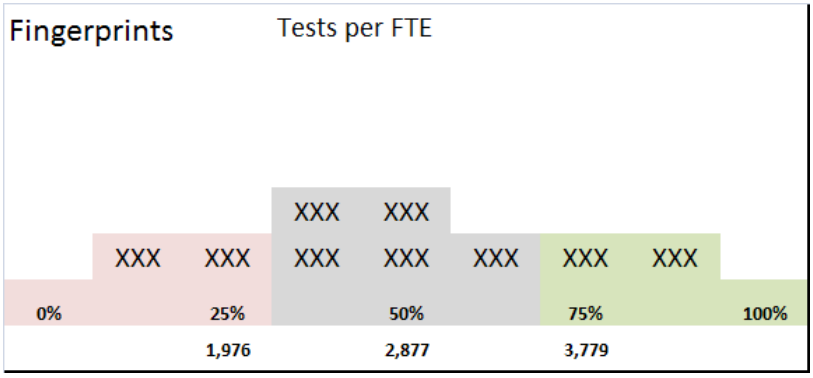

DNA Database
Tests per FTE
XXX XXX XXX XXX XXX
0%
25%
50%
75%
100%
741
1,683
2,625

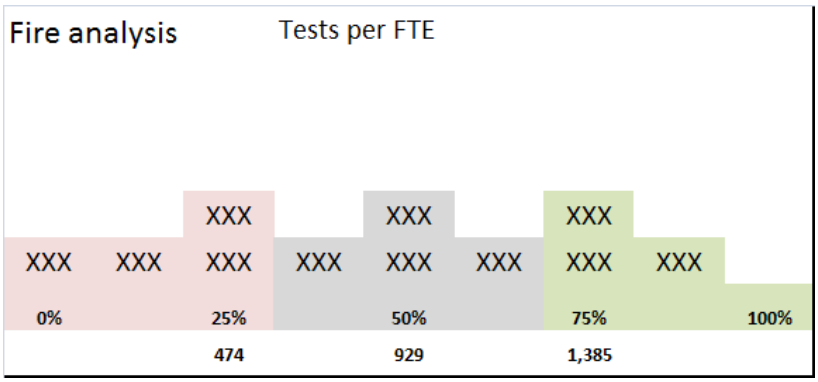

Document Examination
Tests per FTE
XXX
XXX
XXX XXX XXX XXX XXX XXX
0%
25%
50%
75%
100%
144
643
1,142

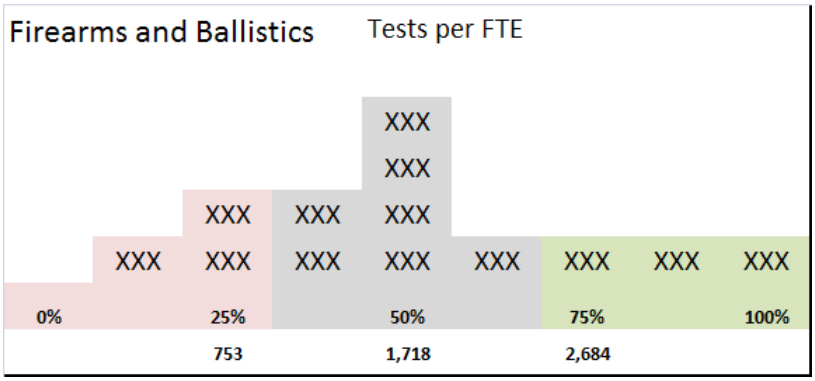

Drugs - Controlled Substances
Tests per FTE
XXX XXX
XXX XXX XXX XXX XXX XXX
0%
25%
50%
75%
100%
2,587
3,345
4,103

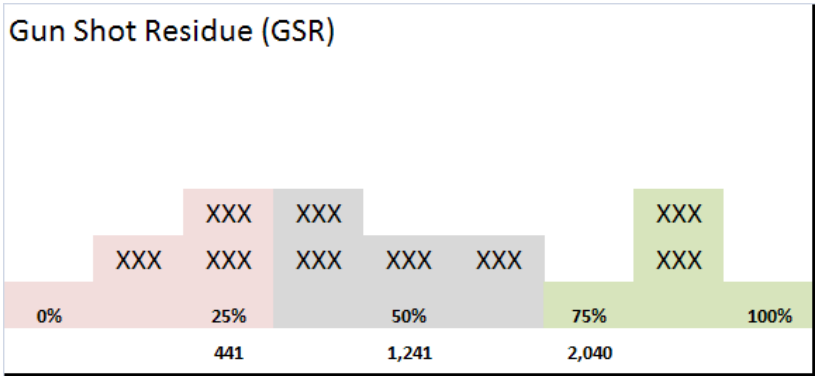

Evidence Screening & Processing
Tests per FTE
XXX
XXX
XXX
XXX
0%
25%
50%
75%
100%
317
1,509
2,701

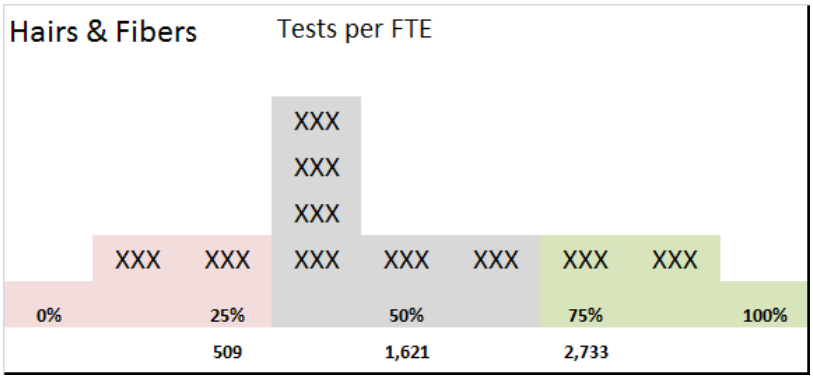

Explosives
Tests per FTE
XXX
XXX
XXX
XXX
XXX
XXX
0%
25%
50%
75%
100%
8
897
1,787

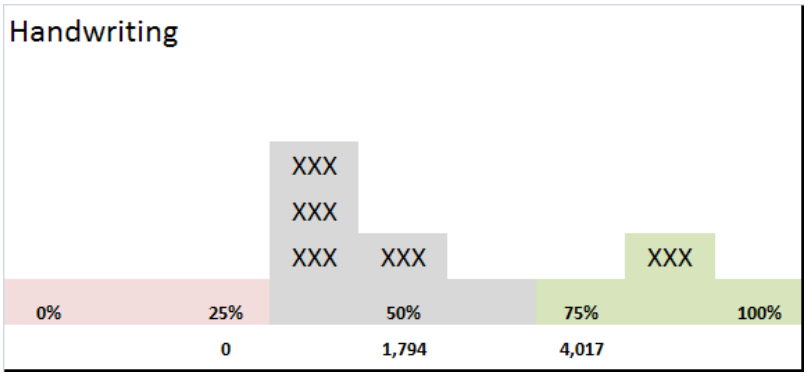

Fingerprints
Tests per FTE
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
0%
25%
50%
75%
100%
1,976
2,877
3,779

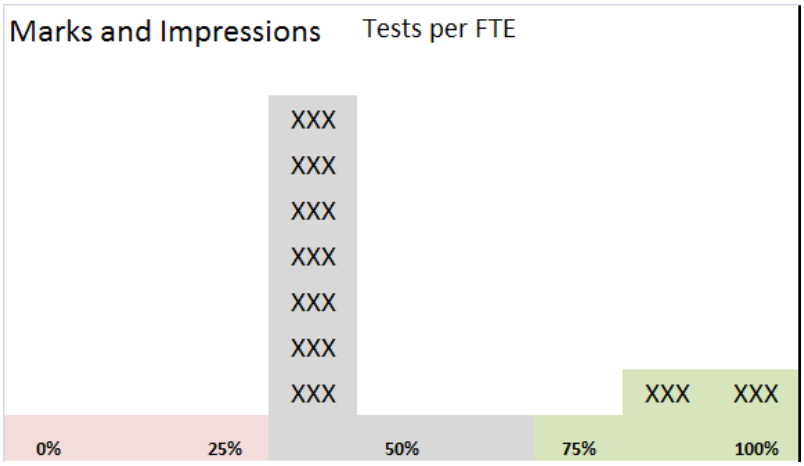

Fire analysis
Tests per FTE
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
0%
25%
50%
75%
100%
474
929
1,385

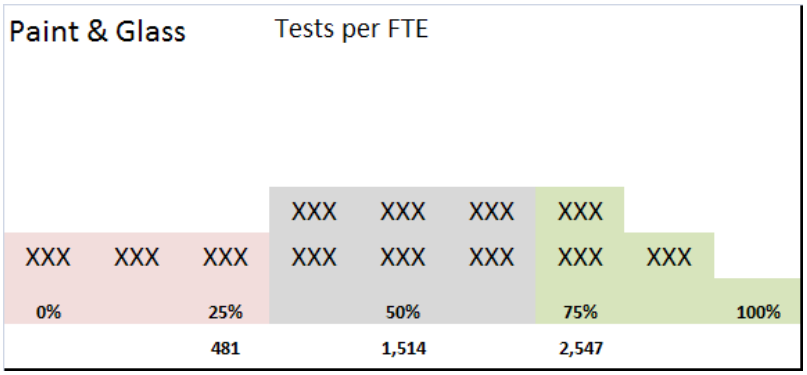

Firearms and Ballistics
Tests per FTE
XXX
XXX
XXX XXX XXX
XXX XXX XXX XXX XXX XXX XXX XXX
0% 25% 50% 75% 100%
753 1,718 2,684

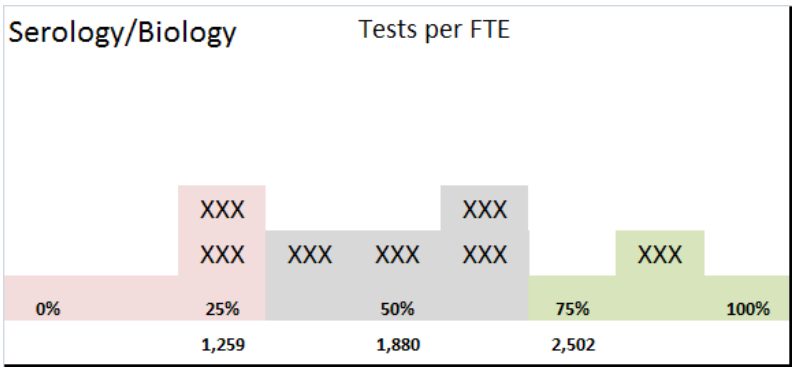

Gun Shot Residue (GSR)
XXX XXX XXX
XXX XXX XXX XXX XXX XXX
0% 25% 50% 75% 100%
441 1,241 2,040

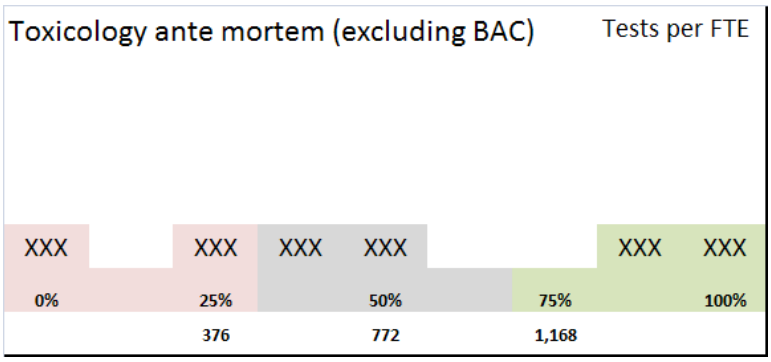

Hairs & Fibers
Tests per FTE
XXX
XXX
XXX
XXX XXX XXX XXX XXX XXX XXX
0% 25% 50% 75% 100%
509 1,621 2,733

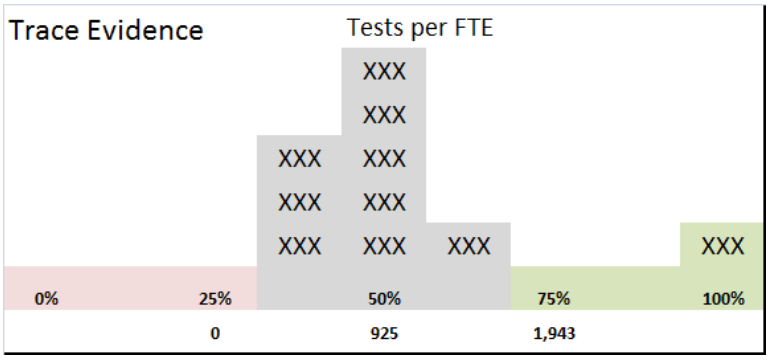

Handwriting
XXX
XXX
XXX XXX XXX
0% 25% 50% 75% 100%
0 1,794 4,017


Marks and Impressions
Tests per FTE
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
0%
25%
50%
75%
100%


Paint & Glass
Tests per FTE
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
0%
25%
50%
75%
100%
481
1,514
2,547


Serology/Biology
Tests per FTE
XXX
XXX
XXX
XXX
XXX
XXX
XXX
XXX
0%
25%
50%
75%
100%
1,259
1,880
2,502


Toxicology ante mortem (excluding BAC)
Tests per FTE
XXX
XXX
XXX
XXX
XXX
XXX
0%
25%
50%
75%
100%
376
772
1,168



Across all of the investigative areas, notice that there is a fair amount of variability in efficiency. Most investigative areas demonstrate large differences in productivity. Those investigative areas with a high coefficient of variation are the areas with the greatest potential gains from a view of best practices. If the highly efficient laboratories can be studied in greater detail, there may be large gains available to other laboratories.

Risk or Quality Management Measures

A variety of efficiency measures are available to evaluate risk management or quality assurance. These include Tests completed relative to area cases, items processed or samples processed. The average value for the most commonly referenced level of detail of these measures by investigative area is presented in Table 2 along with the standard deviation and the coefficient of variation (C.V.)

Investigation area	Mean	Standard Deviation	C.V.
Blood Alcohol	3.73	3.90	1.04
Computer Analysis	13.20	10.18	0.77
Crime Scene Investigation	151.50	171.83	1.13
Digital evidence - Audio & Video	11.86	9.03	0.76
DNA Casework	28.78	51.52	1.79
DNA Database	2.09	2.91	1.39
Document Examination	9.79	11.35	1.16
Drugs - Controlled Substances	384.40	1248.40	3.25
Evidence Screening & Processing	20.49	26.33	1.29
Environmental analysis	80.00	53.74	0.67
Explosives	63.21	64.52	1.02
Fingerprints	317.94	859.93	2.70
Fire analysis	9.83	7.87	0.80
Firearms and Ballistics	104.99	311.73	2.97
Gun Shot Residue (GSR)	13.42	16.07	1.20

Hairs & Fibers	90.03	212.41	2.36
Handwriting	21.85	27.14	1.24
Marks and Impressions	11.63	17.54	1.51
Paint & Glass	35.63	28.11	0.79
Serology/Biology	164.40	403.67	2.46
Toxicology ante mortem (excluding BAC)	5.46	7.33	1.34
Toxicology post mortem (excluding BAC)	4.11	1.39	0.34
Trace Evidence	88.32	233.58	2.64

Table 2—Testing Intensity TEST/CASE

The Foresight study provided a series of examples to provide greater consistency with respect to measurement and interpretation of tests for counting purposes. These results reflect that consistency. Some of the deviations from the mean can be attributed to the mix of cases within an investigative area. Some of deviations from the mean can be attributed to statutory restrictions on the level of testing within a particular case. These deviations will continue to exist. However, discussion with participants noted that there were some deviations that were the result of managerial policies and laboratory practices. As with efficiency improvements, it was apparent that there are best practices at some laboratories that should be shared via additional study that offer to improve performance at underperforming laboratories.

Analytical Process Measures

Not every laboratory will apply identical equipment or techniques for a particular analysis. For other industries, attention is placed with these choices through a look at the allocation of resources for capital equipment, human resources (labor), and other inputs into the production process. These all constitute Analytical Process Measures and include,

KEXP/TOTEXP = Capital Expense/Total Expense

OPEXP/TOTEXP = Operational Expenses/Total Expense

KEXP/LEXP = Capital Expense/Labor Expense

CASEWK/HRS = Casework Hours/FTE Hours

COURTHRS/HRS = Testimony Hours/FTE Hours

FTE_{sup}/FTE = Support Staff FTE/Total Staff FTE

FTE_{Op}/FTE = Operational Staff FTE/Total Staff FTE

FTE_{sci}/FTE_{Op} = Scientists FTE/Operational Staff FTE

A simple comparative ratio to reflect a laboratory's choices is the dollar allocation of resources from the common size statements. If a laboratory has substituted more equipment for personnel, then the manager's question becomes one of assessing whether this change has a positive impact on the laboratory's output. The measure of Personnel (Labor) Expense given Total Expense will have a variety of implications that may be tracked on a regular basis. The ratio used to evaluate analytical process (production function) is:

LEXP/TOTEXP = Total Personnel Expenditures/Total Expenditures

The summary statistics for this measure are presented in Table 3. As it relates to overall performance, this measure may prove to be important when a laboratory deviates to a large extent from the average laboratory. That deviation could signal a different analytical process; for example, it could signal a large capital purchase in a particular year. As such, it is a measure that should be observed over a period of time and not restricted to a single year.

Investigation area	Mean	Standard Deviation	CV
Blood Alcohol	60.43%	14.19%	0.23
Computer Analysis	79.63%	15.04%	0.19
Crime Scene Investigation	70.04%	18.24%	0.26
Digital evidence - Audio & Video	66.88%	5.91%	0.09
DNA Casework	55.96%	10.29%	0.18
DNA Database	43.07%	17.54%	0.41
Document Examination	69.74%	18.43%	0.26
Drugs - Controlled Substances	67.34%	11.17%	0.17
Evidence Screening & Processing	67.42%	11.46%	0.17
Environmental analysis	40.25%	45.58%	1.13
Explosives	63.62%	19.50%	0.31
Fingerprints	72.27%	11.58%	0.16
Fire analysis	70.34%	10.20%	0.15
Firearms and Ballistics	73.29%	11.91%	0.16
Gun Shot Residue (GSR)	73.49%	9.27%	0.13
Hairs & Fibers	70.58%	15.44%	0.22
Handwriting	60.04%	10.29%	0.17
Marks and Impressions	66.83%	25.71%	0.38
Paint & Glass	67.58%	13.81%	0.20
Serology/Biology	69.57%	10.83%	0.16
Toxicology ante mortem (excluding BAC)	65.89%	15.98%	0.24
Toxicology post mortem (excluding BAC)	65.36%	12.55%	0.19
Trace Evidence	65.40%	12.93%	0.20

Table3—Percentage Personnel Expenditures

Notice that the coefficient of variation is small in nearly every case, suggesting that the industry follows fairly similar processes across laboratories. In those cases where the CV is larger, investigation of those laboratories with greater deviation from the mean should first explore whether there was significant equipment expenditure in that year.

Market Condition Measures

Local economic conditions may strongly influence the performance of an individual forensic laboratory. A forensic laboratory may be highly efficient, adopt the most productive analytical procedures, optimize quality, yet fall short comparatively to other laboratories simply because of the local economic conditions, particularly in the labor market. For example, low unemployment/high income geographical areas may skew analytical comparisons to geographical areas with high unemployment or lower wage rates. Further, changes in socio-economic conditions may affect the relative rates of forensic over time; this may in turn affect operational efficiency. The ratio used to evaluate market conditions is:

Average Compensation = Total Personnel Expenditures/Full-time Equivalent Employees

Table 4 presents the average value for this measure. Consider the average worker compensation as one such indicator of market conditions. The ratio of LEXP/FTE = Personnel expense/Full time equivalent employees provides the average expense across all employee compensation. Because the cost of living will vary greatly across locations, it will be more expensive to hire in high cost of living markets as the forensic laboratory is competing with organizations in many industries for the skilled workers it must employ. Similarly, a laboratory could track the expense attributed to other variable costs in the analytical process, VC/CASE = Non-labor Operational Expenses/Cases Processed.

Investigation area	Mean	Standard Deviation	C.V.
Blood Alcohol	$78,534	$18,631	0.24
Computer Analysis	$75,572	$18,189	0.24
Crime Scene Investigation	$86,327	$13,303	0.15
Digital evidence - Audio & Video	$68,948	$24,131	0.35
DNA Casework	$80,004	$29,982	0.37
DNA Database	$57,171	$30,087	0.53
Document Examination	$89,206	$29,732	0.33
Drugs - Controlled Substances	$81,943	$16,778	0.20
Evidence Screening & Processing	$70,380	$24,995	0.36
Environmental analysis	$95,330	$20,858	0.22
Explosives	$108,220	$54,601	0.50
Fingerprints	$83,359	$17,403	0.21
Fire analysis	$107,175	$84,586	0.79

Firearms and Ballistics	$89,082	$20,232	0.23
Gun Shot Residue (GSR)	$97,004	$27,199	0.28
Hairs & Fibers	$94,082	$28,813	0.31
Handwriting	$66,573	$9,575	0.14
Marks and Impressions	$98,310	$32,363	0.33
Paint & Glass	$83,814	$20,905	0.25
Serology/Biology	$83,504	$45,183	0.54
Toxicology ante mortem (excluding BAC)	$75,296	$15,084	0.20
Toxicology post mortem (excluding BAC)	$79,472	$21,703	0.27
Trace Evidence	$95,049	$24,933	0.26

Table4—Average Compensation

The average compensation includes salary and benefits that are paid directly by the employer. There are a few investigative areas that have significant variability in compensation across laboratories. In most cases, this was a reflection of the local market conditions. However, some cases saw this result as a reflection of the makeup of its workforce. For example, costs savings were realized by some laboratories that were able to shed some of the obligations of their highly trained scientists for capable analysts. In other laboratories, the higher salaries were a reflection of the experience of the workforce. Additional study of the human resources issues will shed more light on the best practices and any recommend changes for the industry.

Return on Investment Measures

When economists evaluate an organization in a for-profit industry, the optimization problem is relatively simple. When it comes to the not-for-profit or government entity, the goals are a little more disparate. Each not-for-profit organization has a goal (mission) that is targeted towards some sense of “greater good” that for-profit market solutions do not adequately address. The not-for-profit organization tries to alleviate as much pain and suffering or achieve as much of the “greater good” as it can with the resources at its disposal. And, for these organizations, the resources rarely, if ever, are adequate enough to declare “mission accomplished.” There is always more to be done. For the not-for-profit organization, the optimization problem still exists but is operationalized by maximizing resources, funding or revenues and then using these funds to achieve as much “good” as possible. There are alternative ROI measures that may be computed and tracked, including:

ITEM/TOTEXP	=	Items Processed/Total Expenditures
SAMPLE/TOTEXP	=	Samples Processed/ Total Expenditures
TEST/TOTEXP	=	Tests Completed/ Total Expenditures
REPORT/TOTEXP	=	Reports Completed/ Total Expenditures
BACK30/TOTEXP	=	Backlog Cases/ Total Expenditures

The ratios used to evaluate efficiency measures were:

Cases/TOTEXP = Cases Processed/Total Expenditures

Cost per Case = Total Expenditures/Cases Processed

The latter measure is just the inverse of the former measure, but it is a more intuitive presentation of the data. Table 5 provides the average cost per case by investigative area.

Investigation area	Mean	Standard Deviation	C.V.
Blood Alcohol	$203	$289	1.42
Computer Analysis	$6,232	$6,006	0.96
Crime Scene Investigation	$3,271	$3,489	1.07
Digital evidence - Audio & Video	$970	$1,181	1.22
DNA Casework	$1,486	$740	0.50
DNA Database	$108	$71	0.66
Document Examination	$2,290	$1,539	0.67
Drugs - Controlled Substances	$273	$278	1.02
Evidence Screening & Processing	$1,530	$1,061	0.69
Environmental analysis	$13,981	$354	0.03
Explosives	$18,094	$13,329	0.74
Fingerprints	$433	$204	0.47
Fire analysis	$1,602	$907	0.57
Firearms and Ballistics	$1,048	$749	0.72
Gun Shot Residue (GSR)	$1,444	$1,249	0.86
Hairs & Fibers	$3,728	$3,645	0.98
Handwriting	$2,130	$1,116	0.52
Marks and Impressions	$5,184	$6,070	1.17
Paint & Glass	$4,490	$3,083	0.69
Serology/Biology	$687	$590	0.86
Toxicology ante mortem (excluding BAC)	$911	$1,467	1.61
Toxicology post mortem (excluding BAC)	$1,897	$3,001	1.58
Trace Evidence	$6,620	$9,415	1.42

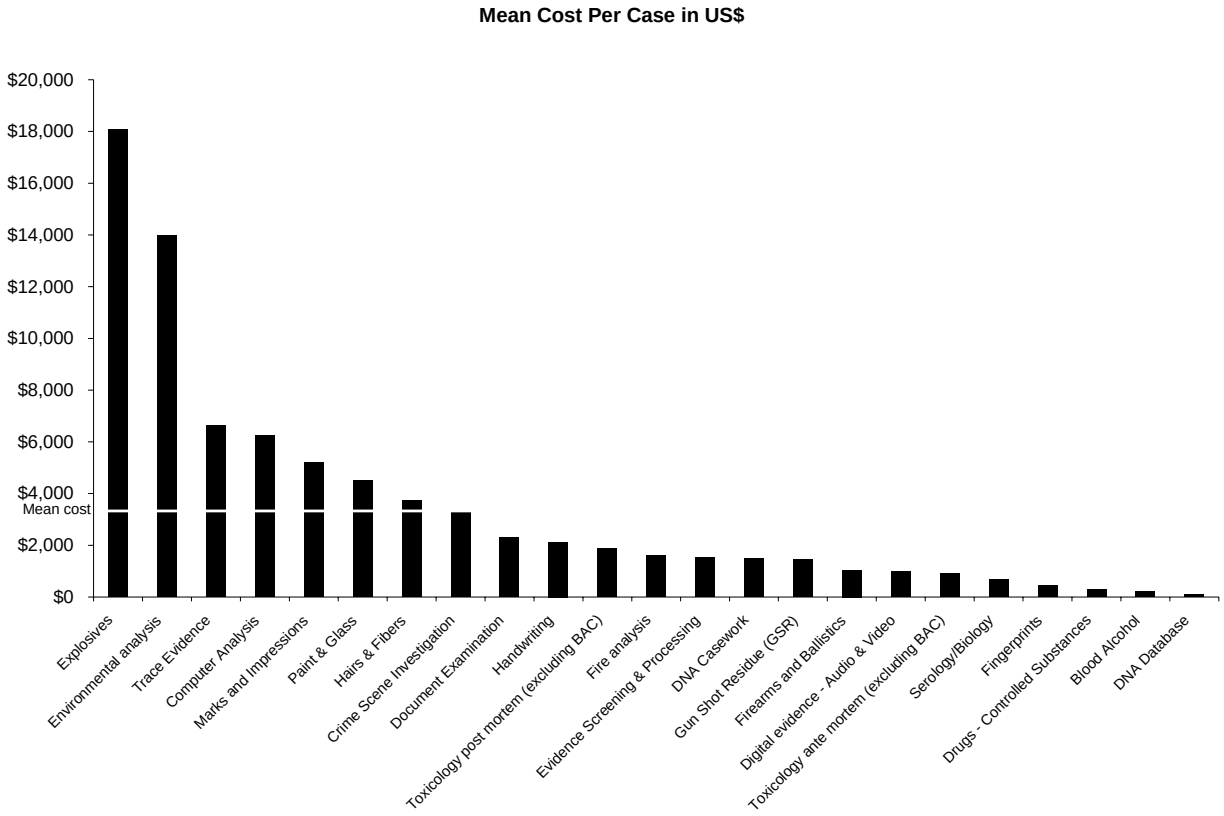
Table 5—Cost per Case

Except for the environmental analysis investigative area, there are a wide range of outcomes in the average cost per case across the investigative areas. To understand why that is the case, examination of best practices should have some great value. Additionally, it is possible to connect the ratios above to get a better look at the reasons behind an individual laboratory's success.

A decomposition of the return on investment measure reveals the relationship and an explanation for performance in any investigative area.

$$\text{Average Cost/Case} = \frac{\text{Average Compensation x Testing Intensity}}{\text{Labor Productivity x Personnel Expenditure Ratio}}$$

In order of greatest to least cost per case, Table 5 can be sorted as shown below with the line indicating the mean of the mean costs per case ($3,418):



Thus, the five tables above are related and can be used to explain overall performance (return on investment or average cost) as it relates to efficiency, market conditions, risk or quality management, and analytical procedure.

Additional Measures

FORESIGHT created but has not completely evaluated numerous other metrics requested by participants or as viewed by other standards in the accounting and finance literature. Not all of

these measures were used for this report but may be provided to individual laboratories for specific evaluative purposes germane to their needs. These measures include:

Correlation between pay and mobility	Analysis of backlog
Correlation between pay and training (per FTE)	Ratio: Staff FTEs / Manager FTEs
Correlation between pay and experience (Ave)	R&D: Hours as a Percent of Total
Turn-Around Times	R&D: V&I Dollars as a Percent of Total Exp.
Casework versus Non-Casework	Training $ / FTE
FTE / Case	Expenditure by area / case
Correlation between T&E and productivity	Expenditure by area / item
Correlation between experience and productivity	Expenditure by area / exam (test)
Case output / FTE (by investigative area)	Gap analysis / best practices
Floor space / FTE	Cost per case by investigative area
Floor space / Case	Training of clients & customers / total hours
FTEs by job type (e.g., analysts) per population	Correlation between training and mobility
Percent of casework by investigative area	Casehours / total hours
Percent of items by investigative area	Training / Demographics

Future publications and reports may incorporate one or more of these or other measures as needed.

Conclusions

With these measures as a baseline, production and efficiency functions can be derived for one or more forensic laboratories. FORESIGHT is open to any forensic laboratory that completes and submits a LabRAT form. By doing so, the participating laboratory will receive a detailed, integrated report showing their metrics compared with the other participants. This report will be an important step in defining what can be improved, what can be changed, and what can be retained for a quality forensic service system.

Reprints of this summary

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Appendix A. FORESIGHT Glossary

Glossary of Definitions

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 as measured at the end of the year.
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.
casework	All laboratory activities involved in examination of cases.
casework time	Total FTE´s for the operational personnel in the investigation area (in hours) subtracted by the hours of R&D and, E&T and support and service given to external partners.
crime	Perceived violation of the law that initiates a case investigation.
direct salary	Total salary paid to employees, including overtime compensations, vacation salary, bonuses, etc.
examinations (exams)	The word QUADRUPOL used for "test"; see both "test" and "sample" in this glossary for the changes adopted by FORESIGHT.
facility expense	Sum of rents, cleaning and garbage collection, security, energy, water, communication, ICT infrastructure and facility maintenance.
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.
full-time researcher	A forensic scientist whose primary responsibility is research and who is not taking part in casework.
investigation area	Area limited by item type and methods as they are listed in the benchmarking model.
investment expense	Sum of purchases of equipment, etc. with a lifetime longer than three years and a cost above $1,000 (alternatively capital expenses).
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 & D), education and training (E & T) and external support services. Non-reporting unit heads are included.
other area	Floor area of space not belonging to laboratories or offices, i.e. corridors, lunch corners, meeting rooms etc. (square feet).
overhead time	Total FTE´s in hours in the investigation area subtracted by the total hours of casework, R&D, E&T and support and service given to external partners.
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.
reporting analyst	An analyst responsible in non-complicated cases (e.g. simple drugs analysis) for performing the examination of the items submitted, interpreting the analysis results, writing the analysis report and, if necessary, providing factual evidence for the court.
reporting scientist	The forensic scientist responsible in a particular case for performing or directing the examination of the items submitted, interpreting the findings, writing the report and providing evidence of fact and opinion for the court.
representation expense	The costs for hosting guests: lunches, dinners, coffees offered by the lab, and presents given to guests or during visits abroad, etc.
running operational expense	Others cost than investment costs, personnel costs and facilities costs, e.g. consumables, traveling, QA, literature, contracting, representation, service and maintenance, information and advertisement.
sample	An item of evidence or a portion of an item of evidence that generates a reported result.
scientist in training	An individual with no reporting rights being trained to become a reporting scientist.
student hours	The sum of teaching hours in a course multiplied by the number of students attending the particular course.

support personnel	Forensic laboratory staff providing various internal support services. Management and administration personnel not belonging to the operational units are included.
teaching hours	Time spent teaching in the lecture-room in hours (60 min)
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.
total expense	The sum of the direct expenses (personnel, operating, and investment) and any administrative or other overhead expenses.
total funding	The sum of all funding sources including jurisdictional budgeting, grant awards, bequests, and revenue sources.
total items	Includes all items to which the laboratory assigns an item or tracking number. This is different than the number of items the laboratory receives (the lab may split items up for analysis).
workload	Total time spent on all work related to job, including overtime.

Appendix B. Definitions for Investigative Areas

	Definitions of Investigation Areas[1]
Accident Investigation	All non-traffic accident investigations, such as work-related accidents.
Biology (Non-DNA)	The detection, collection, and non-DNA analysis of biological fluids.[2]
Blood Alcohol	The analysis of blood or breath samples to detect the presence of and quantify the amount of alcohol.
Computer Analysis	The analysis of computers, computerized consumer goods, and associated hardware for data retrieval and sourcing.
Crime Scene Investigation	The collection, analysis, and processing of locations for evidence relating to a criminal incident.
Digital evidence - Audio & Video	The analysis of multimedia audio, video, and still image materials, such as surveillance recordings and video enhancement.
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, excluding handwriting analysis.
Drugs - Controlled Substances	The analysis of solid dosage licit and illicit drugs, including pre-cursor materials.
Entomology	Forensic entomology is the application of the study of arthropods, including insects, to criminal or legal cases.
Evidence Screening & Processing	The detection, collection, and processing of physical evidence in the laboratory for potential additional analysis.
Environmental analysis	The analysis of naturally occuring materials, such as soil or water, for foreign substances with criminal implications.
Explosives	The analysis of energetic materials in pre- and post-blast incidents.
Fingerprints	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 toolmarks.
Forensic engineering and material science	Failure and performance analysis of materials and constructions.
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).
Hairs & Fibers	The analysis of human and animal hairs (non-DNA) and textile fibers as trace evidence.
Handwriting	The evaluation of hand written materials to categorize or identify a writer.
Marks and Impressions	The analysis of physical patterns received and retained through the interaction of objects of various hardness, including shoeprints and tire tracks.
Odontology	The identification of human remains through dental materials, for example by postmortem X-rays of the teeth compared to antemortem X-rays. Some forensic odontologists also analyze and compare bitemarks.
Paint & Glass	The analysis of paints—generically, coatings—and glass as trace evidence.
Road accident reconstruction	Analysis of criminal incidents involving vehicles and accidents (hit and run, for example).
Speech & Audio	The analysis of live and recorded vocalizations in criminal investigations.
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.

Other Specialties	Other forensic science applications not covered by the other categories.

1 All definitions are derived from QUADRUPOL or ILAC.

2 Definitions in italics are new and were created for FORESIGHT.

Appendix C. LabRAT forms

Welcome to the Laboratory Reporting and Analysis Tool (LabRAT), part of the FORESIGHT project. The following worksheets address a variety of questions regarding the allocation of resources within your laboratory. With each worksheet, the requested items are highlighted in the yellow shaded cells. Other cells, with white background, may have data in the form of automated calculations. Do not worry about completion of items in those white background cells.

Organization (Data Source)	
Fiscal Year (e.g., 2007)	
Fiscal Year Period (e.g., Jul 1-Jun 30)	

Laboratory Detail		**Laboratory LabRAT project manager**	
Jurisdiction (federal, state, local, private)		**Contact Information:**	
Size Population Served		Phone:	
Geographic Size Served		Fax:	
Number of separate facilities		email:	
		Mailing Address:	
LIMS Provider / Version			
Standard Work Week (hrs)		City:	
Facilities - Square Feet		State/Prov:	
Administrative Office Area		Country:	
Laboratory Area		Zip:	
Other Area			

Please provide a brief descriptive profile of your organization and laboratories:

Please provide a brief description of any anomolies in the reported year versus a "normal" year of operation.

Amount Budgeted (from all sources of funding) for the Investigation area for the year	Investigation area	*In each cell, indicate the actual dollar expenditure for the Fiscal Year.*															0							
		Capital Expenditures current year	Capital Expenditures previous four years	Operational Staff Salary	Support Staff Salary	Benefits	Overtime and Temporary	Chemicals, reagents, consumables, gases	Traveling (non-training related)	QA and accreditation	Literature purchased	Subcontracting lab. investigations (cases)	Other subcontracts (e.g. consulting)	Representation costs	Service of instruments	Information / publications produced	Advertisements (for vacancies)	Non-instrument Repairs & maintenance	Equipment leasing	Facilities Rent - Leasing	Utilities	Telecommunications	Other	Total Expenditures
	Accident Investigation																							0
	Blood Alcohol																							0
	Computer Analysis																							0
	Crime Scene Investigation																							0
	Digital evidence - Audio & Video																							0
	DNA Casework																							0
	DNA Database																							0
	Document Examination																							0
	Drugs - Controlled Substances																							0
	Entomology																							0
	Evidence Screening & Processing																							0
	Environmental analysis																							0
	Explosives																							0
	Fingerprints																							0
	Fire analysis																							0
	Firearms and Ballistics *																							0
	Forensic engineering and material science																							0
	Forensic Pathology																							0
	Gun Shot Residue (GSR)																							0
	Hairs & Fibers																							0
	Handwriting																							0
	Marks and Impressions **																							0
	Odontology																							0
	Paint & Glass																							0
	Road accident reconstruction																							0
	Serology/Biology																							0
	Speech & Audio																							0
	Toxicology ante mortem (excluding BAC)																							0
	Toxicology post mortem (excluding BAC)																							0
	Trace Evidence																							0
	Administration and Support																							
	Other Specialities (describe below)																							
	0																							0
	0																							0
	0																							0
	0																							0
	0																							0
	0																							0
	0																							0
	0																							0
$0	TOTAL																							0
	TOTAL	$0							$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
*Includes toolmarks	**Includes tires and shoes	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	$0

In the box below, add any special notes regarding your completion of this worksheet.

0

In each cell, enter the requested number for that row's investigation area

Investigation area	case areas	total items	items outsourced	items examined internally	total samples from items examined internally	tests on samples examined internally	area reports	Median turn around time, days from last submission (internal)	Median turn around time, days from first submission (internal)	Median turn around time for analyst, days	open area cases at end of year	open area cases older than 30 days at end of year (backlog)	number of institutional cases in one area only	Floor area (sq ft)	Hrs in casework	Operational Staff FTE	Support Staff FTE
Accident Investigation																	
Blood Alcohol																	
Computer Analysis																	
Crime Scene Investigation																	
Digital evidence - Audio & Video																	
DNA Casework																	
DNA Database																	
Document Examination																	
Drugs - Controlled Substances																	
Entomology																	
Evidence Screening & Processing																	
Environmental analysis																	
Explosives																	
Fingerprints																	
Fire analysis																	
Firearms and Ballistics *																	
Forensic engineering and material science																	
Forensic Pathology																	
Gun Shot Residue (GSR)																	
Hairs & Fibers																	
Handwriting																	
Marks and Impressions **																	
Odontology																	
Paint & Glass																	
Road accident reconstruction																	
Serology/Biology																	
Speech & Audio																	
Toxicology ante mortem (excluding BAC)																	
Toxicology post mortem (excluding BAC)																	
Trace Evidence																	
Other Specialties (describe below)																	
TOTAL	-	-	-	-		-	-	-	-	-	-	-	-	-	-	0.00	0.00

*Includes toolmarks
**Includes tires and shoes

Investigation area	Expenditures Total	Personnel Expenditures	FTE	Area Cases	Items	Samples	Tests	Cost per Case	Cost per Item	Cost per Test	Average Compensation	Personnel Budget / Total Budget	Cases per FTE	Tests per Case	Tests per Sample	Tests per FTE
Accident Investigation	$0	$0	0.00	0	0	0	0									
Blood Alcohol	$0	$0	0.00	0	0	0	0									
Computer Analysis	$0	$0	0.00	0	0	0	0									
Crime Scene Investigation	$0	$0	0.00	0	0	0	0									
Digital evidence - Audio & Video	$0	$0	0.00	0	0	0	0									
DNA Casework	$0	$0	0.00	0	0	0	0									
DNA Database	$0	$0	0.00	0	0	0	0									
Document Examination	$0	$0	0.00	0	0	0	0									
Drugs - Controlled Substances	$0	$0	0.00	0	0	0	0									
Entomology	$0	$0	0.00	0	0	0	0									
Evidence Screening & Processing	$0	$0	0.00	0	0	0	0									
Environmental analysis	$0	$0	0.00	0	0	0	0									
Explosives	$0	$0	0.00	0	0	0	0									
Fingerprints	$0	$0	0.00	0	0	0	0									
Fire analysis	$0	$0	0.00	0	0	0	0									
Firearms and Ballistics *	$0	$0	0.00	0	0	0	0									
Forensic engineering and material science	$0	$0	0.00	0	0	0	0									
Forensic Pathology	$0	$0	0.00	0	0	0	0									
Gun Shot Residue (GSR)	$0	$0	0.00	0	0	0	0									
Hairs & Fibers	$0	$0	0.00	0	0	0	0									
Handwriting	$0	$0	0.00	0	0	0	0									
Marks and Impressions **	$0	$0	0.00	0	0	0	0									
Odontology	$0	$0	0.00	0	0	0	0									
Paint & Glass	$0	$0	0.00	0	0	0	0									
Road accident reconstruction	$0	$0	0.00	0	0	0	0									
Serology/Biology	$0	$0	0.00	0	0	0	0									
Speech & Audio	$0	$0	0.00	0	0	0	0									
Toxicology ante mortem (excluding BAC)	$0	$0	0.00	0	0	0	0									
Toxicology post mortem (excluding BAC)	$0	$0	0.00	0	0	0	0									
Trace Evidence	$0	$0	0.00	0	0	0	0									
Other Specialties (describe below)																
0	$0	$0	0.00	0	0	0	0									
0	$0	$0	0.00	0	0	0	0									
0	$0	$0	0.00	0	0	0	0									
0	$0	$0	0.00	0	0	0	0									
0	$0	$0	0.00	0	0	0	0									
0	$0	$0	0.00	0	0	0	0									
0	$0	$0	0.00	0	0	0	0									
0	$0	$0	0.00	0	0	0	0									
	$0	$0	$0	$0	$0	$0	$0									

Appendix D. Examples of counting Items, Samples, and Tests

Drug Case: *A large gym bag is submitted; it contains 50 smaller baggies consistent with individual purchase size amounts in the illicit drug trade. The laboratory's policy is to sample 50% of the suspect material.*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted		
Drug Case	1	25	75	**Weight**	**Presumptive**	**Confirmatory**
1. One large bag (not tested)						
2. Fifty (50) small baggies (assuming a 50% sampling rule)				25	25	25

Firearms Case: *A weapon is seized from a suspect in a homicide case; two bullets are removed from the victim's body. In the second example, 10 bullets from the scene are submitted.*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted		
Firearms case	2 or 3	3	4	**Function Test**	**Test firing**	**Comparison**
1. Weapon				1	1	
2. Two (2) bullets from body						2
or						
3. Ten (10) bullets from scene	11	11	12	1	1	10

Fingerprints case: *Two soda cans and three latent lifts are submitted from the scene as well as two sets of tenprint cards from the suspects.*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted			
Fingerprints case	7	7	18	**Visual**	**Develop (2 @)**	**Comparison**	**Photography**
1. Two (2) soda cans (1 print @)		*1 print @*		2	4	4	2
2. Three (3) latent lifts		*3*				6	
3. Two (2) tenprint cards*		*2*					

* *Each tenprint set counts as 1 Item, to include major case prints, palms, etc.*

Biology/Serology case: *In a case of sexual assault, the kit, the victim's underwear, and a bedsheet are submitted; due to the context of the crime, the bedsheet is not examined. The laboratory does not perform microscopic hair examinations.*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted			
Biology/Serology case	4	4	17	**Visual**	**AP**	**P30**	**Microscopic**
1. Sexual Assault Kit							
1.1 Vaginal swab					1	1	1
1.2 Oral swab					1	1	1
1.3 Anal swab					1	1	1
1.4 Hair sample (not tested)							
1.5 Victim known sample							
2. Underwear (Two stains: one +, one --)				2	2	2	2
3. Bedsheet (not tested)							
4. Suspect known sample							

DNA case (from Biology case): *In the same case as above, the known samples of the victim and the suspect are submitted along with the one positive stain from the serology examination.*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted			
DNA case (from Biology case)	3	4	16	**Extraction**	**Quantificaton**	**Amplification**	**Separation**
1. Sexual Assault Kit							
1.1 Vaginal swab				1	1	1	1
1.2 Oral swab							
1.3 Anal swab							
1.4 Hair sample (not tested)							
1.5 Victim known sample				1	1	1	1
2. Underwear (Two stains: one positive, one negative)				1	1	1	1
3. Bedsheets (not tested)							
4. Suspect known sample				1	1	1	1

Toxicology, antemortem case: *In a routine submission, a blood and a urine sample are submitted; because of laboratory policy, only one sample is analyzed.*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted	
Toxicology, antemortem case	2	1 or 2	3 or 6	**Instrumental**	**GC-MS**
1. Blood sample				1	2
2. Urine sample (not tested)					

Toxicology, postmore case: *In a routine autopsy, a blood and a urine sample are submitted; because of laboratory policy, only two samples are analyzed.*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted		
Toxicology, postmortem case	3	2 or 4	12 or 24	**Instrumental**	**LC-MS**	**GC-MS**
1. Blood sample				1	2	
2. Urine sample (not tested)						
3. Vitreous humor sample				1	2	3

Trace: Gunshot Residue Case

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted	
One GSR kit	1	3	6	**Microscopic**	**SEM**
				1	1

Trace: Glass Comparison Case:*One bag containing known glass; one bag containing questioned glass.*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted					
Glass comparison case	2	2	12	**Micro-scopic**	**Thickness**	**UV-fluor-escence**	**Density**	**RI**	**SEM/EDS**
1. Known glass				1	1	1	1	1	1
2. Questioned									

Trace: Ignitable liquids case:*One can containing debris*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted	
Ignitable Liquids Case	1	1	2	**Odor/Visual**	**GC-MS**
1. Debris				1	1

Trace: Paint Comparison Case:*One bag containing known paint; one bag containing questioned paint.*

	Total Items	total samples from items examined internally	tests on samples examined internally	Tests Conducted				
Paint comparison case	2	2	14	**Micro-scopic**	**Physical**	**Solubilities (3)**	**IR**	**SEM/EDS**
1. Known paint				1	1	3	1	1
2. Questioned paint				1	1	3	1	1