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Key Performance Indicators and Managerial Analysis for Forensic Laboratories

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Abstract *Forensic laboratories generate a great deal of data from casework activities across investigative areas, personnel and budget allocations, and corresponding expenditures. This paper investigates ways in which laboratories can make data-driven managerial decisions through the regular extraction of key performance indicators from commonly available data sources. A laboratory's performance indicators can then be compared to peer laboratory performance to search for best practices, determine in-house trends, manage scarce resources, and provide quantitative support for the justification of additional resources.*

Keywords Economics, finance, forensic labs, quality issues, management

Introduction

Forensic laboratories face the classic economic problem—how to allocate limited resources with increasing demand for services while maintaining high-quality standards. Questions abound with respect to performance of the laboratory, given budgeted resources (Dale and Becker, 2004; Koussiafes, 2004). How does the laboratory director know:

- If resources are appropriately allocated?
- If the laboratory performance is efficient?
- Whether alternative practices might result in improved, high-quality services?
- Whether sufficient safeguards are in place to assure the quality of analysis?
- Whether there is adequate investment for equipment, training, and development to enhance future analytical technique?
- Whether the laboratory is optimizing the return on investment for its constituency?

Similar questions face every organization, whether it is a manufacturing plant choosing the optimal level of production, a hospital deciding upon its level of emergency care, or a county government selecting which roads to repair. All organizations must address the economic problem and determine how to allocate scarce resources. And once a strategy has been implemented, how does the organization know whether its choices are appropriate? That is, how does the laboratory measure and monitor its attempts to make optimal decisions in meeting the mandates of its mission?

Fortunately, other industries have examined this economic problem (Kaskinen, 2007; Love et al., 2008; Smith, 2007). The answers in other industries to similar questions have left us with some powerful tools that can be applied to forensic laboratories (Bielski, 2007; Brooks, 2007; Petaschnick, 2008; Reilly, 1997). From accounting we learn that common-size financial statements can transform the financial statements of individual entities into size-adjusted analysis tools that can be easily compared against industry standards. From business finance we learn that transforming absolute dollar-performance measures into size-adjusted ratio measures permits any business to evaluate its allocation of resources into measures of liquidity, efficiency, risk, return, and market assessment.

In the sections that follow, these lessons are applied to forensic laboratories. In the first section, the technique of common-size statements is introduced for the budget allocations of laboratories. A common-size budget statement will permit a laboratory to consider the allocation of resources as a percentage of the total budget and

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compare to the industry average or to a select group of the most successful laboratories for signs of improvement. The third section addresses issues of language and measurement standards across the forensic laboratory industry. Unfortunately, there is no universally accepted terminology for forensic laboratories. The common language adopted in the European Quadrupol and U.S. Foresight studies is presented as the standard by which the remaining measures will be defined. In the fourth section, key performance indicators are developed that address issues in several areas of concern for forensic laboratories: return on investment, efficiency, risk/quality assurance, analytical process, and measures of market condition. Concluding comments follow with some warnings signs regarding data-driven management.

Common-Size Statements

Within any industry we find organizations of varying size, and forensic laboratories are no different. How do we compare a statewide forensic laboratory with a smaller county forensic laboratory, or a large metropolitan forensic laboratory with a forensic laboratory with a nationwide mandate? In the financial-services industry, a similar problem exists: the method in which we compare the community bank to the regional bank to the international bank; in healthcare, the need to compare the community health center to the regional hospital to the major teaching hospital; in food service, comparing the neighborhood restaurant to the national chain restaurant. How do you compare the performance of two organizations with similar missions, but unequal size?

To compare the decisions and performances of different-sized organizations, accountants introduced the concept of common-size statements. As applied to forensic laboratories, consider the allocation of funding within a forensic laboratory. With a common-size budget, the funds allocated to each budget category are divided by the total budget, and each line-item budgeted area is expressed as a percentage of the total, thus enabling comparison across laboratories or across time for a specific laboratory. When the common-size budget reveals significant differences in the allocation of funding across expense areas, it raises a red flag for the laboratory manager to look more closely at that area to see if practices and policies are moving the laboratory into the desired strategic direction.

Consider Tables 1 and 2, examples of two forensic laboratories of different size. Laboratory Small has total funding and expenditures of less than $10 million annually, while Laboratory Large has total funding in excess of $50 million annually. Small spends $5.7 million for salaries while Large spends $26.5 million for the same expense category. Is Small spending too much on personnel (all else being equal), or perhaps, not enough? What about the personnel expense allocation of Large? Is it too much, too little, or just right? And what about the other expense categories or the source of funds—are there concerns that jump out?

Table 1. Dollar Budgets for Laboratory Small and Laboratory Large

Funding	*Laboratory Small*	*Laboratory Large*
Budget - Jurisdiction	$7,700,000	$52,700,000
Grants	$2,050,000	$0
Other funding sources (including revenue)	$50,000	$3,800,000
Total Funding	**$9,385,500**	**$56,500,000**
Personnel costs		
Direct salaries	$5,725,000	$26,500,000
Overtime & Temps	$605,000	$285,000
Benefits	$1,850,000	$9,200,000
Personnel development & training	$65,000	$805,000
Total Personnel	**$8,245,000**	**$36,790,000**
Running operational costs		
Chemicals, reagents, consumables, gases	$530,000	$3,450,000
Travel	$4,000	$310,000
Subcontracting	$25,000	$1,525,000
Leasing	$290,000	$940,000
Service of Instruments	$455,000	$810,000
Repairs & maintenance	$35,000	$750,000
Utilities	$47,500	$610,000
Telecommunications	$24,000	$305,000
Other operational costs	$12,500	$2,250,000
Total Operational Cost	**$1,423,000**	**$10,950,000**
Capital Expenditures (Investment costs)		
DNA Laboratory instruments/ equipment	$0	$2,525,000
Non-DNA Laboratory instruments/equipment	$0	$1,100,000
Furniture	$15,000	$275,000
Information technology	$17,500	$1,400,000
Facilities > $10,000	$0	$99,900
Vehicles	$0	$127,500
Total Investment	**$30,000**	**$5,527,400**
Surplus (Deficit)	**$102,000**	**$3,232,600**

Table 1 illustrates the dollar budgets for Laboratory Small and Laboratory Large. As presented, it would take a very experienced laboratory director to immediately draw some perspective about these two scenarios. Laboratory Large is nearly six times the size of Laboratory Small; its personnel expenses are roughly 4.5 times that of Small, while operational costs are more than 7.5 times the size. Large invests over $5.5 million in capital expenditures while Small only invests $30,000; and Large boasts a year-end surplus that is nearly one third the size of Small's entire budget. The direct comparison of the dollar funding and expenditures is very difficult to critically assess.

Table 2. Common-Size Budgets for Laboratory Small and Laboratory Large

Funding	*Laboratory Small common Size Budget*	*Laboratory Large common Size Budget*	*Average Forensic Laboratory*
Budget – Jurisdiction	76.71%	93.25%	87.32%
Grants	21.84%	0.00%	9.92%
Other funding sources (including revenue)	1.44%	6.75%	2.76%
Total Funding	**100%**	**100%**	**100%**
Personnel expenses			
Direct salaries	56.74%	47.07%	58.08%
Overtime & Temps	6.45%	0.51%	2.68%
Benefits	19.71%	16.34%	17.37%
Personnel development & training	0.69%	1.43%	0.92%
Total Personnel	**83.59%**	**65.35%**	**79.05%**
Running operational expenses			
Chemicals, reagents, consumables, gases	5.65%	6.13%	6.12%
Travel	0.04%	0.55%	0.38%
Subcontracting	0.27%	2.71%	4.39%
Leasing	3.09%	1.67%	4.83%
Service of Instruments	4.85%	1.44%	1.59%
Repairs & maintenance	0.37%	1.33%	0.71%
Utilities	0.51%	1.08%	1.34%
Telecommunications	0.26%	0.54%	0.46%
Other operational costs	0.13%	4.00%	0.97%
Total Operational Cost	**15.16%**	**19.45%**	**20.79%**
Capital Expenditures (Investment expenses)			
DNA Laboratory instruments/ equipment	0.00%	4.48%	1.47%
Non-DNA Laboratory instruments/equipment	0.94%	1.95%	1.43%
Furniture	0.16%	0.49%	0.37%
Information technology	0.19%	2.49%	0.89%
Facilities > $10,000	0.00%	0.18%	0.24%
Vehicles	0.00%	0.23%	1.04%
Total Investment	**1.28%**	**9.82%**	**5.45%**
Surplus (Deficit)	**1.04%**	**5.72%**	**3.37%**

A common-size presentation delivers that immediacy as it converts each dollar category to a percentage of the entire budget. To make the conversion for Laboratory Small, which has total funding of $9.8 million, every line item for funding source or expense category is divided by the total funding level for the entire laboratory. Similarly for Laboratory Large, every line item is divided by its total funding level of $56.5 million. The results are illustrated in Table 2 for Laboratory Small and Laboratory Large. For additional analytical value, the corresponding percentages of funding and expense allocation for the average comparable forensic laboratory are presented. (Note that Table 2 is fabricated for purposes of illustration and is not the result of an industry study.)

In this cross-sectional presentation, the common-size statement serves to wave red flags at areas that require further investigation. If a laboratory's budget categorization differs significantly from the norm, laboratory management should dig further to develop an understanding and explanation. Recognize, however, that merely being different from the average does not indicate that a problem exists; it may be the case that the difference is expected due to the nature of the missions of the two laboratories. Also, note that the industry average includes all organizations in the industry, both the efficient and the inefficient, and does not necessarily represent the ideal budget splits—just an average.

Nevertheless, consider the red flags raised by Table 2. In an examination of the source of funds, laboratories Small and Large both differ from the average laboratory. Small has a very high percentage of its funding (relative to the average laboratory funding) that comes from grants, while Large lacks the grants but has a relatively high percentage of funding that arises from its jurisdictional allotment. What might these red flags indicate? In the case of laboratory Large, further investigation reveals that it is a national laboratory that is not eligible for most of the available grant funding; from this investigation, the difference is easily explained. For laboratory Small, there is some concern as the jurisdictional budget (78.57%) is smaller than the total personnel expense of 84.13% , and may threaten long-term viability of some employment and laboratory performance.

Looking deeper into personnel expenses, Small devotes a much higher percentage of its budget towards direct salaries, overload, and temporary workers. This difference suggests that Small take a look at the salary levels and distribution of its workforce to look for any possible inefficient allocation of labor resources. Large, on the other hand, has a relatively lower total expense for benefits and may want to investigate what impact the reduced benefits may have on its workforce.

The long-term expense for capital sends some signals for additional investigation. In most environments, the miniscule investment in plant and equipment by Small would not bode well for the future. This percentage should be compared with recent years to see if this is a trend or merely an anomaly found in the current year. Further, when coupled with the high percentage spent in the service of equipment category, a red flag raises some initial concern for the long-term health of the laboratory—the high service expense possibly indicates older equipment. Laboratory Large, however, is making relatively large investments in DNA laboratory equipment and information technology, and is investing nearly twice that of the average laboratory. This may bode well for the future, but may also signal a need to monitor the use of equipment for efficiency versus overfunding.

Finally, note the final line category of laboratory "surpluses." Laboratory Small has little excess; Laboratory Large has a much higher percentage of unused funds compared to both Small and the industry average. Further investigation is warranted. Is Large overfunded, too big to be run efficiently, or even too slow to operate? Could the seemingly lower funding for personnel be masked by having too many unfilled positions? The benefit of common-size statements is in raising these types of red flags to help direct the laboratory manager's inquiries.

A Common Nomenclature

Gather together a group of forensic laboratory directors and ask each to define what they mean by a case, a sample, an item, a test, or a host of other terms and you will hear as many different responses as the number of individuals who are quizzed. Each laboratory jurisdiction has developed its own language by practice or perhaps by statute. Unfortunately, disparate language in the same science makes comparison and the development of industry standards difficult; as yet universally accepted industry measures for forensic laboratories are lacking. To overcome this difficulty, the 2003 European Quadrupol study began to put a common language in place when it studied the national forensic laboratories of four countries. That common set of definitions and measures from Quadrupol was adopted and enhanced in the 2006–2009 U.S. Foresight study. In the present analysis, this language is adopted for the key performance indicators that follow.

The complete Quadrupol/Foresight glossary may be found in Appendix A. That glossary includes the following definitions presented in Table 3, which will be used in the next section.

Additionally, the European Quadrupol and U.S. Foresight studies separated functions of forensic laboratories into a series of investigative areas. Individual forensic laboratories will likely have some differences in their organizational chart with the standard definitions from these two studies. However, some separation was required to permit the detailed information that can be learned and shared with the industry, and these investigative areas are adopted in the present paper. Appendix B details the definitions of 'investigation areas' from the Quadrupol/Foresight Projects.

Ratio Metrics

While laboratories may have similar missions, there are differences such as populations served, geographic coverage, jurisdiction, legislative mandates, breadth of investigative areas, staffing, and existing facilities, that make direct comparisons of productivity across laboratories difficult. To find meaningful metrics across the range of forensic laboratories, it is helpful to make adjustments for resources and responsibilities through the creation of ratios. Similar to the common-size analysis tool discussed above, ratios provide *relative* measures that make for easier comparisons across disparate operational entities. Ratios permit a laboratory to measure its 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 forensic laboratory. Consider the various sources of data from a laboratory, which include information on casework, budgets, and personnel. In the analysis that follows, some of the 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 laboratory 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.

Efficiency Measures

Not all forensic laboratories are built, provisioned, or staffed in the same manner. However, given the resources available, we can ask the question: How was a laboratory or an investigative area within a forensic laboratory

Table 3. Selective Quadrupol/Foresight Definitions

Term	*Definition*	*Notation*
Backlog	Open cases older than 30 days as measured at the end of the year.	BACK30
Case - Area Case	A request for examination in one forensic investigation area. An area case is a subset of an institute case.	CASE
Case - Institute Case	A request from a forensic laboratory "customer" that includes forensic investigations in one or more investigative areas.	ICASE
Full-Time Equivalent (FTE)	The work input of a full-time employee working for one full year.	FTE
Investment Expense	Sum of purchases of equipment, etc., with a lifetime longer than three years and a cost above $1,000 (alternatively capital expenses).	KEXP
Item	A single object for examination submitted to the laboratory. Note: one item may be investigated and counted in several investigation areas.	ITEM
Laboratory Area	Floor area used for forensic investigation, including sample and consumable storage rooms.	SQFT or SQ.m
Overhead Time	Total FTEs in hours in the investigation area subtracted by the total hours of casework, research & development, education & training, and support & service given to external partners.	OVRHD
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).	LEXP
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.	REPORT
Sample	An item of evidence or a portion of an item of evidence that generates a reported result.	SAMPLE
Test	An analytical process, including but not limited to visual examination, instrumental analysis, presumptive evaluations, enhancement techniques, extractions, quantization, microscopic techniques, and comparative examinations. This does not include technical or administrative reviews.	TEST
Total Expense	The sum of the direct expenses (personnel, operating, and investment) and any administrative or other overhead expenses.	TOTEXP
Total Funding	The sum of all funding sources including jurisdictional budgeting, grant awards, bequests, and revenue sources.	TOTFUND

able to perform relative to the resources at its disposal? Consider some ratios that provide an indication of efficiency. One measure of the resources for a particular laboratory is the physical size of the facility. While it is natural to expect that a larger facility will be able to process a higher volume, we can track how well it performs relative to its available facility and make comparisons across the industry or across time.

Consider one such measure, CASE/SQ.m (area cases processed/laboratory area). Although each laboratory will differ according to personnel, plant and equipment, this measure provides a simple comparative measure across facility space allocations. We proxy those resources via the size of the laboratory (or the size dedicated to a given investigative area) and consider the output: production/analyses performed. An individual laboratory can then compare similar investigative areas within the laboratory as well as their performance compared to laboratories of any size. As a rough generalization, a higher ratio suggests some greater efficiency. When this ratio is compared to the same measure for peer laboratories, the measure offers the laboratory and its stakeholders an opportunity to assess the general productivity against an appropriately selected benchmark. For example, benchmarks might be specifically identified laboratories with similar missions or services, or with industry averages.

Other productivity measures of great value compare the productivity of capital or labor. Consider the largest single expenditure in most laboratories—investment in personnel. The measure TEST/FTE (tests performed/full-time equivalent employees) offers a quick measure of the output per person in the laboratory. This is an easily calculated measure that provides both comparison to peer laboratory benchmarks and offers a regular (monthly, quarterly, or annual) measure for trend analysis within a laboratory.

The efficiency measures and benchmarks a forensic laboratory manager should choose are a local decision to meet the informational needs of the various stakeholders of the laboratory. In addition to those above, consider the following possible ratio measures:

ITEM/FTE = Items processed/FTE employees
SAMPLE/FTE = Samples processed/FTE employees

TEST/FTE = Tests completed/FTE employees
REPORT/FTE = Reports completed/FTE employees
CASE/SQFT = Area cases processed/laboratory square feet area
ITEM/SQFT = Items processed/laboratory square feet area
SAMPLE/SQFT = Samples processed/laboratory square feet area
TEST/SQFT = Tests completed/laboratory square feet area
REPORT/SQFT = Reports completed/laboratory square feet area
ITEM/SQ.m = Items processed/laboratory square meter area
SAMPLE/SQ.m = Samples processed/laboratory square meter area
TEST/SQ.m = Tests completed/laboratory square meter area
REPORT/SQ.m = Reports completed/laboratory square meter area
FTE/FTE_{BUD} = Actual FTE employees/budgeted FTE employees

Each of these measures is created from easily obtained laboratory information. The periodic calculation of these measures, whether annually, quarterly, or monthly, provides an immediate data-analysis tool for management. Each investigative area within a forensic laboratory can track ratios of interest and either compare that period's performance to past performance or make comparisons to an industry average or to specific peer labs to gain a sense of productivity.

These measures of efficiency are the type of measures that are followed in most industries. For example, capacity utilization measures are usually important to track. Since resources are limited whereas the potential output is unlimited, a laboratory may want to keep track of how well it uses the resources at its disposal. How quickly does management respond to vacancies and fill those vacancies? The last of the listed measures compares the allocation of resources versus the budgeting of those resources. Further, given each laboratory's uniqueness, it may have additional efficiency measures that may be followed to track other concerns, issues, or points of emphasis.

Quality/Risk Management

The regular calculation and reporting of ratios can help monitor the laboratory in other areas besides efficiency. A second such category relates to measures of quality- or risk-management measures. A laboratory faces multiple problems with its processing of cases, given limited resources. Errors may occur from either commission or omission. The former may receive the bulk of the attention as errors may occur from poor calibration of equipment, human error, insufficient samples, less sophisticated techniques, etc. Likewise, errors of omission may result from delays in processing evidence. These delays may result in contamination, recidivism, or other losses.

One quality measure is the separate testing of the accuracy of a laboratory's normal output in which a random selection of prior test results is selected and retested to verify the accuracy of the original testing. At the conclusion of the retesting of this random sample of procedures, an error rate can then be calculated and used as a sample measure of quality. While this independent verification of results is a normal part of most quality-assurance programs in any forensic laboratory, it does represent a statistical sample, is not a census of the entire laboratory, and is subject to individual laboratory choices on allowable error in the sampling process. Going back to the efficiency metrics discussed above, some labs are required to retest every sample. Such double-testing assures high quality but would most likely result in relatively lower return-on-investment measures when compared across the industry.

There are proxies that address quality and do not require the collection of any additional data. Consider the measure TEST/CASE (tests completed/cases processed). The quality-assurance processes of the previous paragraph would be partially revealed in this measure. That is, a quality-assurance program within a laboratory that increased the sample size for retesting would be revealed as a higher numerator (tests completed) in this measure. This would also be true for any case in which a greater number of separately revealing examinations were conducted. Both the test error rate and the ratio TEST/CASE provide some monitoring of the errors of commission.

For errors of omission, a reasonable proxy would attend to the number of cases not yet processed. A ratio of BACK30/CASE (backlog cases in excess of thirty days/total cases processed) provides a useful trend measure that can be monitored from regularly collected data and used on a regular basis to assess the work not being completed.

As with efficiency, there are a variety of other ratio measures that are easily constructed and may have pertinent information content to an individual forensic laboratory. These include the following:

ERROR/SAMPLE = Commission sample error rate
ERROR/ITEM = Commission item error rate
ERROR/CASE = Commission case error rate
TEST/ITEM = Tests completed/items processed
TEST/SAMPLE = Tests completed/samples processed
SAMPLE/CASE = Samples processed/case processed

Analytical Process (Production Function)

Over time, new scientific achievements, new instrumentation, and new techniques are introduced that affect the processes by which samples are analyzed. Not every organization will select the same equipment or the same techniques for analysis. This is true in other industries as well as with forensic laboratories. 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.

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. A measure LEXP/TOTEXP (personnel [labor] expense/total expense) will have a variety of implications that may be tracked on a regular basis.

Other analytical process measures include a look at the other expenditure categories as a percentage of total expenditures, the capital expenditure to labor expense ratio analyzed, time management measures, or even the allocation of labor resources across investigative areas. Dale and Becker (2004) suggest alternative hiring practices to optimize the use of limited budgets and change the mix of scientists versus other technical workers in the laboratory for which these ratios offer some use.

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

Market Conditions

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, and 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 forensics over time; this may in turn affect operational efficiency. To illustrate, consider a situation with declining economic performance and increasing forensic rates; such a socio-economic condition may cause the forensic laboratory to reach its capacity, causing some operational dysfunction that was not present when forensic rates were lower and the forensic laboratory operated at optimal volumes. Or across countries, there may be social/cultural choices that have an effect on individual laboratory performance that need to be part of operational comparisons.

The Bureau of Labor Statistics (www.bls.gov), the Census Bureau (www.census.gov), state economic authorities, and other public sources (www.usa.gov) provide individual market data for comparison. But the data from individual laboratories also reflect information about these market conditions and are readily available to the forensic laboratory director and managers. A combination of data from the budgetary process and from a laboratory's personnel database and case volume metrics can permit some regular monitoring of the local market effects on performance.

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).

Return on Investment (ROI)

Ultimately, the questions to be answered come down to the overall performance of the forensic laboratory.

- How does the laboratory compare to its peers?
- Is the forensic laboratory taking sufficient care of the funds provided by its stakeholders?
- Does management have the laboratory on a path of continuous improvement?

To evaluate the return, we first must address what the laboratory is attempting to accomplish in such a way that comparisons across laboratories may yield meaningful results.

"If you don't know where you are going, then any path will get you there." It becomes paramount that organizations take a careful look at their mission, vision, and values, and establish goals that are consistent with their charge. In the case of forensic laboratories, there are some commonalities, but the underlying goals and affiliated optimization decision will differ across organizations. There are three general categories into which organizations tend to fall, and all three categories apply to the broadly defined industry of forensic laboratories. The categories include for-profit, not-for-profit, and government entities.

When economists evaluate an organization in a for-profit industry, the optimization problem is relatively simple. The decisions of the business are guided by a wealth-maximization criterion and actions become relatively easy to judge based upon that standard. And, although we don't know what the highest attainable level of wealth might actually be, we can determine whether managerial actions have improved the performance of the business or resulted in decline. That is, either an action served to increase stock price (or some other appropriate measure of wealth such as profits) or it did not.

When it comes to the not-for-profit or government entity, the goals are a little more disparate. However, we can make some generalizations that extend to the industry of forensic laboratories. Each nonprofit organization has a goal (mission) that is targeted towards some sense of "greater good" that for-profit market solutions do not adequately address. The nonprofit organization tries to alleviate as much pain and suffering or to 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 nonprofit 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.

For the government entity, leadership faces a problem similar to that of the not-for-profit organization. Its sights are set on some "greater good" that pure for-profit market solutions have failed to adequately address. Managerial decisions in this environment differ from that of the nonprofit manager in that funding/resources/revenues are predetermined by some extra-organizational (e.g., legislative) process, and the manager is left with an exogenous budget constraint. Given a budget for funding, the optimization problem for management becomes one of getting the most output from the limited funds. However, the other side of the coin is that managers, by maximizing output for a given budget, are actually minimizing the cost per unit of output.

Summarizing, the generalization of objectives for each type of organization:

- Not-for-profits maximize revenue;
- Government entities minimize cost; and
- For-profit organizations maximize the difference between revenue and cost.

Because the government organization dominates the forensic laboratory industry, the ROI measures that are most appropriate address the mission of government forensic laboratories. Consider then the mandate to correctly process as many cases as possible for a given budget allocation. The measure CASE/TOTEXP (area cases processed/total expenditures) is a tractable measure that has direct comparison across laboratories or across time for trends within an individual laboratory, and may be appropriate for comparisons across investigative areas that are similar in nature. The metric is easily computed from existing databases within the laboratory and can be a regularly (monthly, quarterly, annually) produced measure at the laboratory level or constructed by investigative area within the laboratory.

Note that the inverse of this ratio, cost per case (TOTEXP/CASE), is also an item of interest to the laboratory and all of its stakeholders. In fact, the prior discussion on maximization of the cases processed for a given budget allocation may be turned around as the problem of minimizing the average cost of processing a case. Additionally, objectives may be measured in terms of reducing backlog as a measure of return.

There are other related ROI measures that may be computed and tracked. Some of these alternatives:

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

Cautions and Conclusions

Forensic laboratories routinely generate data from casework performance across investigative areas, personnel and budget allocations, and corresponding expenses. This article 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 forensic 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 forensic laboratory 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.

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.

References

Bielski, L. 2007. KPI: Your metrics should tell a story. *ABA Banking J.* 10: 66–68.

Brooks, M.G. 2008. Getting a handle on analytics for strategic success. *Healthcare Finan. Manag.* 7: 100–104.

Dale, M.W., & W.S. Becker. 2004. A case study of forensic scientist turnover. *Forensic Sci. Commun.* 6: 1–9.

Kaskinen, J. Creating a best-in-class KPI program. 2007. *Strategic Finance.* 10: 29–33.

Koussiafes, P.M. 2004. Public forensic laboratory budget issues *Forensic Sci. Commun.* 6: 1–7.

Love, D., L. Revere, & K. Black. 2008. A current look at the key performance measures considered critical by health care leaders. *J. Health Care Finance* 34: 19–33.

Petaschnick, J. 2008. Using key performance indicators wisely. *Health Care Collector*, 22: 7–9.

Reilly, F.K. 1997. The impact of inflation on ROE, growth and stock prices. *Finan. Serv. Rev.*, 6: 1–17.

Smith, F.O. 2007. Asset management and the search for actionable intelligence. *Control Eng.*, 12: 40–44.

Appendix A: Nomenclature Established by Quadrupol and U.S. Foresight Projects

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 older than 30 days as measured at the end of the year.
Case - Institute Case	A request from a forensic laboratory “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 FTEs 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 U.S. 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 FTEs 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 minutes).
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 laboratory may split items up for analysis).
Workload	Total time spent on all work related to job, including overtime.
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.
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.

Appendix B: Definition of Investigation Areas from the Quadrupol and U.S. Foresight Projects

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 precursor 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 occurring 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 handwritten 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 bite marks.
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).
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.
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.