Trends, Challenges and Strategy in the Forensic Science Sector

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Introduction

The forensic science sector is in transition. New insights, technologies, and customers, combined with falling costs and increasing capabilities cause the sector to grow rapidly. As a consequence the role of forensic laboratories is changing. Today's laboratories are able to investigate more and a greater variety of traces, and to extract more information from less material, than ever before. Forensic IT[2] has opened a completely new category of investigation, as specialists explore digital traces on information carriers such as cell phones, laptops, and car computers. Meanwhile, advances in the study of DNA have made it possible to investigate minute traces and even provide information on the physical characteristics of the donor. In addition, all this information can now be produced more quickly than was ever thought possible. Due to these developments, rapid and well-founded reconstructions of events based on trace patterns found at crime scenes are becoming a tantalizing possibility. And these advantages come at a lower cost than many conventional investigative techniques.

As a result, the role of forensic science is changing. Whereas before, it was cast in a supporting role, it is now set to become the playmaker in many types of investigation, providing quick and reliable information on scenarios and suspects and thus, in a sense, directing the efforts of investigators. At the same time, forensics is changing from a profession in which individual experience and expertise of practitioners play a dominant role to one where skilled knowledge workers are integrated in an increasingly complex infrastructure of empirical science and cutting-edge technology.

Taking advantage of these developments to achieve the full potential of the forensic sector will naturally require some adjustment. Despite the sector's rapid growth in recent years, its structure remains largely unchanged. With more than 400 forensic laboratories in the US alone and a somewhat smaller, but still very large, number in Europe, it is a rather fragmented field. Most of

[2] Forensic Information Technology

these laboratories are primarily production units that lack sufficient mass or funding to conduct research, or to develop innovative products and services. Furthermore, this lack of critical mass creates major organizational vulnerabilities, which are in part responsible for the backlogs that haunt many forensic laboratories.

This paper presents an overview, from the standpoint of the Netherlands Forensic Institute (NFI), of some of the trends and pressures that will affect the structure and governance of the sector today and in the years to come. The paper also outlines a way forward, based on measures that the NFI has itself taken to address these challenges.

1. Growth—one of the main trends in forensics today

One of the clearest and most important trends in forensics is its remarkable growth over the past 15 years. At the NFI, the number of cases handled per year is now six times what it was in 2000. In fact, the caseload has grown more in the past 15 years than in the previous 50. In the same period, the NFI's workforce has nearly tripled, growing from about 200 to 600 people. This is clearly part of a larger trend, with caseloads growing steadily at forensic laboratories around the world. Although the recent budget cuts and the economic downturn may temporarily slow the growth of the forensic sector, the fundamental drivers of change persist and will continue to assert themselves.

Factors driving growth

The growth in forensics has been driven by three main factors: (1) the introduction of new technological capabilities, (2) increased general awareness among customers regarding the value and efficiency of forensic science, and (3) the advent of new types of customers from outside the scope of traditional forensics. Let us look at these factors in turn.

New technological capabilities

Much of the recent growth in forensics has resulted from the introduction of new technologies, most notably high-tech biometrics (predominantly forensic DNA), forensic information technology (IT), and forensic chemistry. Just twenty years ago, the first two of these disciplines were not practiced at the NFI; today, they are the largest and fastest growing disciplines at the Institute.

That these new technologies should lead to growth is not surprising. When any new investigative technique is introduced, the pressure to put it into practice quickly increases. Of course, in forensics—as in other fields (e.g., health care)—ethical and quality issues may need to be resolved before a new technique can be used. Otherwise, if it provides valuable information, there will be a strong demand for it to be used immediately and on a wide scale. Since, in this way, any new scientific insight or technology creates its own demand, forensic innovations are likely to continue to spur growth in the field.

It is significant that the three disciplines mentioned above (forensic DNA, IT, and chemistry) do not simply add new and refined technological capabilities to the forensics toolbox. They also address new classes of trace evidence—classes that previously may not have been collected and analyzed. This applies both to biometrics and to forensic IT, but the discipline of forensic IT is particularly significant in this context, as it opens up a whole new world of trace evidence. Today, it is almost impossible to prevent leaving digital traces—in cell phones, on computers, on the Internet, in digital surveillance cameras, in an ATM, in a navigation system, in a car's on-board computer, and so on. People have a symbiotic relationship with both the physical and the digital world. This has profound consequences for forensics, because everything we do leaves a trace in these worlds. It will therefore become increasingly important that forensic service providers be able to retrieve relevant data from all available digital sources and to analyze these intelligently.

Of course, additional growth is also generated through the continuous improvement of existing technologies. As they become more sensitive, the amount of relevant information that can be retrieved from traces will increase, as will the number of traces that can be analyzed in the first place. For example, 15 years ago, a relatively large sample was needed for reliable forensic DNA analysis. Today, forensic laboratories need just a fraction of that: often no more than 50 picograms. Traces that in the past would have yielded no relevant information can now change the course of an investigation.

Moreover, advances in technology mean that forensic laboratories are able to do much more with the same resources (in money terms) than before—so that the value of the laboratory as a whole has increased significantly.

Greater awareness of the value, efficiency and potential of forensics

The use of forensic investigations has increased not only due to the advent of new technologies but also due to an increased awareness of what forensics has to offer. Existing and potential end-users, the press and the public are all more aware today of the extent of forensic capabilities. This, in turn, is generating an increasing demand. Forensic investigation is gradually assuming a more central and high-profile role, and is becoming an essential tool for law enforcement, homeland defense, and others entrusted with maintaining justice, social order and security. Increasingly, court cases depend on DNA evidence, security and terrorism threats are being prevented on the basis of digital traces, and a wide variety of investigators are taking an interest in what forensics has to offer them.

Historically, forensic science has served primarily as the tool of prosecutors in preparation for trial, not necessarily as a tool of investigators. With the advent of faster methods and forensic databases (DNA, fingerprints, firearms, etc.) over the past several decades, forensic science is becoming an invaluable tool in criminal investigations and intelligence, even before a suspect has been identified. For example, investigators can now compare

questioned traces collected from crime scenes or victims with large database pools of known perpetrators, frequently leading to the identification of suspects who would otherwise remain unknown.

As users become more aware of the benefits of the new tools and expertise available, they see new ways to use forensic science. For example, the police are under great pressure to apprehend criminals while at the same time ruling out innocent civilians as suspects. Forensics can help them meet that need by providing reliable information through technical means (i.e., without harassing innocent citizens). This increased awareness of what advanced forensics has to offer is leading to increased demand on the part of traditional customers of forensics laboratories.

New customers

The capabilities of forensic service providers have not passed unnoticed in domains outside of criminal justice and law enforcement. In fact, a wide range of governmental organizations—involved in everything from defense and intelligence to administrative law and regulatory oversight—are using forensics in their investigations. This new demand for forensic science is a main driver of growth in the sector as a whole. Nevertheless, not many traditional crime labs are taking advantage of this fact.

Of course, new customers have different needs from those within the criminal justice system (police, prosecutors and the judiciary). For example, the type of information required and the balance between speed and accuracy may be quite different. Accordingly, in recent years, many of these organizations have created their own specialized forensic units and, in some organizations, their own databases. However, these units are often small and somewhat disconnected from the wider forensic community. This has increased the fragmentation of the forensics sector as a whole, and has occasionally resulted in some organizations “reinventing the wheel.” Nonetheless, these changes also represent an opportunity for the forensic sector. Serving a broader customer base not only reduces organizational

vulnerability, but can also give rise to improved services at lower costs through economies of scale. The atypical requirements of new types of customers stimulate innovation and drive the development of new knowledge, which will ultimately benefit all customers.

As a result of these shifts, a new outlook of the forensic community is emerging. It no longer solely provides forensic services in the fields of law enforcement and criminal justice. Forensic institutes become first and foremost high-tech knowledge hubs, filled with knowledge workers who deliver their services to the (mostly government) agencies that may require these and who enrich the hub in the process. At the NFI, this process could be observed at first hand: by serving non-traditional customers, inside and outside of the Netherlands in 17 countries (at the time of writing), the organization has acquired capabilities and experience that it would not otherwise have been able to obtain, and that are now also available to "traditional" customers. As knowledge hubs, forensic institutes become more valuable if they enlarge the network to which they belong and in which the operate.

Non-traditional customers include ministries of defense, municipalities, intelligence agencies, benefit and tax fraud investigators, the financial market regulator, transport safety boards, competition authorities, and international bodies, such as the international tribunals and criminal courts, but also Europol, Interpol, the IAEA, and the United Nations.

2. Customer focus

The current heightened awareness of forensic science, together with the recognition of its value, means that users and customers not only make greater use of it, but also place greater reliance on it. In short, forensics has moved from occupying a supporting—almost behind-the-scenes—role to becoming a key protagonist. It has, for many users, become "mission critical." As a result, customers are becoming increasingly demanding, subjecting what they receive from their suppliers to ever-closer scrutiny. Consequently, suppliers will need to pay much more attention to their customers' needs.

Identifying customers' primary needs

Forensic laboratories supply their customers with "value-added" information—specifically, about past events and behaviors, as well as about the individuals involved in these events. This information is obtained from the traces that resulted from these events and behaviors. All customers want the supplier laboratory to provide as much relevant information from available traces as possible, and they want the information to be reliable and objective. They do not want the information to depend on the particular forensic investigator handling the case; and, if necessary, they want the forensic investigators to be able to show a solid scientific basis for their conclusions.

Customers also want the laboratory to be able to handle as many trace investigations as possible, because in general (though not always) a larger number of trace investigations yields more information. It also reduces the risk, down the line, that police investigators or prosecutors will be criticized for failing to order trace investigations that are potentially exculpatory, or for failing to do everything possible to apprehend the criminals. When forensic laboratories have a fixed budget, the drive to increase the total output of the laboratory implies that the average cost per investigation has to be reduced.

To most customers of forensic laboratories, receiving the results of the forensic investigation as quickly as possible is extremely important. This is especially true in the intelligence gathering and investigation phases, when time is of the essence. After a crime has been committed, the first 48 hours are often critical in the investigation. In the intelligence phase, being able to analyze traces quickly and reliably can mean the difference between being able to prevent a crime (such as a terrorist attack) or not. The value and impact of forensics increase greatly when results can be delivered quickly.

In other words, the primary needs of the customer can be summarized as follows: more, better, faster, cheaper. In fact, “more”, “faster” and “cheaper” are highly correlated from an organizational and governance point of view, as will be discussed below. The forensic community has historically paid less passionate attention to these customer needs than to the technical content of the forensic trades and the individual skills of the practitioners. In most cases, the costs of individual forensic investigations are not considered at all, either directly or indirectly. Many forensic investigators, laboratory directors, and even customers, actually resist the idea that costs should play any role in the decision-making process before committing to forensic investigations. The implicit belief seems to be that one cannot and should not let financial considerations play such a key role when important societal issues (such as apprehending a criminal and dispensing justice) are at stake. However, since open-ended financial arrangements are an illusion, the practical results of this way of thinking are backlogs, stagnation, and a far-from-optimal—even unknowing—allocation of scarce resources.

All this is changing, however, and will continue to change due to the increasing reliance on forensic investigations and the pressure this puts on forensic laboratories. The same can be said about the drive to increase the information value extracted from traces, as well as the scientific basis and objectivity of forensic conclusions. Both require focused and customer-oriented research and development. However, at the moment, partly because of the arts-and-crafts culture of the forensic field, and partly

because of the fragmented structure of the sector (see the previous section), there is a lack of R&D of this type.

Achieving more, better, and more valuable information

Forensic laboratories can increase the value of the information they provide in at least three ways. The first is by increasing reliability by strengthening objectivity and scientific underpinning. The second is by providing more information at "activity" level, i.e., information that reveals how traces fit together in larger patterns of crime related activity. Finally, laboratories can enhance the information they offer by developing tools and methods that bring to light traces that have hitherto been unavailable because they are imperceptible to the human senses.

Improving scientific underpinning

Up to just a few decades ago, forensic science had more in common with a collection of arts and crafts than with a mature science. In some areas, forensics is essentially still in the pre-scientific era, a fact reflected in the observation by the National Academy of Sciences (NAS) that some forensic disciplines lack a scientific basis.[3] Clearly, if the interpretations made by forensic scientists are not objective or lack a strong scientific underpinning, the value of the information and interpretations forensic labs provide is diminished. The arts-and-crafts culture, the small scale of most forensic laboratories, and the high pressure on throughput, have had the result that the scientific and technological development of the field have not been as rapid as it could have been. In addition, knowledge is often not shared and managed, but resides with skilled, individual practitioners. In essence, these professionals become their own measuring instruments, and the database from which they operate and evaluate forensic evidence is based on personal

[3] *Strengthening Forensic Science in the United States: A Path Forward, NAS,* 2009: "The simple reality is that the interpretation of evidence is not always based on scientific studies to determine its validity. This is a serious problem. Although research has been done in some disciplines, there is a notable dearth of peer-reviewed, published studies establishing the scientific bases and validity of many forensic methods"… "The fact is that many forensic tests have never been exposed to stringent scientific scrutiny. Most of these techniques were developed in crime laboratories to aid the investigation of evidence from a particular crime scene, and researching their limitations and foundations was never a top priority."

experience. Consequently, interpretations are more subjective than is often realized. To a certain extent, this is probably unavoidable, but it would be too easy to say that it is *entirely* unavoidable. With empirical scientific research, it should be possible to strengthen the scientific basis of many forensic disciplines.

Providing activity-level information

A second way in which laboratories can increase the value of the information they deliver is to provide customers with more information at "activity" level. Many forensic laboratories restrict themselves to "source level" investigations, focusing on the origin and composition of a given trace. However, from the point of view of the customer, it is also important how and when the trace was made; i.e., what events transpired to leave a certain trace (or pattern of traces). In the case of DNA and latent fingerprints found at a crime scene, for instance, it would be useful to know not only to whom the DNA or latent fingerprints belong, but also what activity led to the evidence being deposited there. Was it an activity related to the crime, or was it entirely unrelated? So far, relatively little research has been carried out to increase the capabilities of forensic investigations at activity level. In those cases where forensic practitioners have included some analysis at activity level in their reports, it is often based on the practitioner's particular experience, rather than any empirical scientific research. However, the added value provided by activity-level information suggests that such research is highly desirable. It is, however, expensive, time-consuming, and requires substantial case-loads to be able to create the necessary empirical databases. Critical mass and cooperation among laboratories are both essential in this regard.

Detecting, recording, and retrieving minute traces

A third way in which laboratories can increase the value of the information they provide to customers is to gain access to traces left at the crime scene that are currently too small to detect with the human senses. Detecting such traces is becoming a new "holy grail" of forensics. Although it is currently

possible to investigate such minute traces in the laboratory, it is still impossible (within a reasonable timeframe) to detect, register and represent all these important traces not merely in isolation but also in the three-dimensional patterns in which they occur at the crime scene. It may be possible to investigate 50 picograms of cell material containing DNA in the laboratory, but how does one find such small quantities at a crime scene? This is certainly an important R&D challenge. (Incidentally, it should be noted that the growing numbers of traces that will become available in this way make it all the more important that forensic laboratories take steps to increase their efficiency and productivity, because increased numbers of traces will steadily increase the caseload: see below.)

Shortening delivery times

As was discussed above, quick delivery is one of the most important needs that customers of forensic laboratories articulate. In fact, as forensic investigations are increasingly becoming "mission critical" to customers, forensic laboratories have to reconcile themselves to the fact that customers—if given the choice—would like the results immediately. This does not mean that customers in all circumstances *need* the results immediately, or that they are always in a position to act on the information the moment it is provided. However, regardless of how fast investigators are able to act on the laboratory's results, it is a laudable goal for forensic laboratories to reduce the odds of being the choke point in the critical path of criminal investigations. Furthermore, suppliers (forensic laboratories in this case) usually do not have all the information necessary to determine what is important to the customer, and there may be subjective or even emotional (but not necessarily irrelevant) reasons why customers want fast delivery. However, historically the sense of urgency felt by customers regarding fast delivery was not always shared fully by the forensic community. The NFI was no exception. However, as will be discussed below, the problem is not caused exclusively by a lack of focus on speed by forensic

laboratories. It is also caused by the institutional arrangements and financing structures in which the forensic sector operates.

There are at least three ways in which delivery times can be shortened: by solving the backlog problem; by improving process management; and by creating new, faster technologies.

The backlog problem

Two factors that have a significant impact on the caseload of forensic laboratories are the crime rate and the scientific and technological capabilities of the laboratories. The way in which the crime rate impacts forensic laboratories is similar to the way it influences the broader law enforcement community. However, the impact of scientific progress and technological innovation is far more complicated, and clearly sets forensic labs apart from their main customers. Advances in forensic technology tend to increase the caseload of laboratories—sometimes dramatically—even when the crime rate is going down. Conversely, to some extent powerful forensic techniques replace more “traditional” and time-consuming investigative methods, or at a minimum can provide more focus to a criminal investigation. These phenomena could be clearly observed in The Netherlands, where the crime rate has gone down in the past decade, while the number of cases the NFI handles has increased by a factor of six. This increase is almost exclusively confined to the forensic fields that have experienced significant technological advances. The largest increase in demand has been witnessed in forensic DNA analysis, forensic IT, and forensic chemistry. However, more recently, technological and scientific advances in other fields – such as new fingermark detection methods and the evaluation of partial fingermarks – have also had the effect of greatly increasing the demand in these fields. As soon as new, powerful and validated forensic techniques become available, customers want to use them in their criminal investigations.

These “technology-driven” demand shocks, during which the demand for certain forensic services increases quickly, are often not adequately factored into the budgetary models used to allocate resources to the different entities within the law enforcement community (if such models exist at all). Forensic laboratories are usually not paid for the amount of work they are commissioned to do (the demand), but are instead given a fixed budget that is supposed to cover all the work sent to them. An increase in demand caused, for example, by an innovative forensic method, does not automatically lead to a commensurate increase in financing, which could then be invested to create additional production capacity. Conversely, demand is not tempered by a “fee”, and most labs do not have production agreements (i.e., Service Level Agreements) with their customers, limiting the amount of work that can be commissioned. Forensic investigations cost money—sometimes a lot of money—but the parties commissioning these investigations are often not conscious of this fact. For them, the forensic investigations are “free”, and they behave as if there are no budgetary or capacity constraints. This is the double-edged sword that has created backlogs all over the world. Due to the existing institutional arrangements and funding structures, budgets are not adjusted quickly enough when demand shocks present themselves, and customers are not disciplined by any kind of fee structure, or production agreements, that signal to them that forensic investigations cost money and that resources are limited. The inevitable result of this is a backlog. The fields that are hardest hit are often those that are most dynamic and that show the most scientific and technological progress. The huge DNA backlogs in many forensic laboratories around the world are an illustration of this phenomenon.

When resources are limited, as is invariably the case, prioritization becomes a necessity. However, the fact that forensic services are treated as if they were “free of charge” robs customers of the opportunity to evaluate costs versus potential benefits, given the fact that resources are limited. The inevitable result is that scarce resources are not being used in the most

efficient and effective way, and significant waste is occurring even as backlogs pile up.

Some may object (for a variety of reasons) to any notion of "charging" for forensic investigations. This is perhaps in part because they fear commercialization. However, what is being discussed here is not some sort of commercialization scheme, but rather a more efficient allocation method, i.e., one that prevents backlogs and waste, and leads to more informed and conscious prioritization mechanisms. It requires a repudiation of the double illusion that forensic investigations cost nothing and that forensic laboratories have unlimited capacity. It does not necessitate the establishment of any for-profit entity. Indeed, given the large number of cases that pass through forensic laboratories each month, it is neither practical nor necessary for them to start sending out bills for every investigation completed. This would create a huge and undesirable bureaucracy between agencies. An easier way—and one that has been implemented at the NFI—is to reach an annual agreement with the main customers on the number of forensic services (of different types) that the laboratory will deliver during the following year. The total "fee" of these SLAs is then equal to the agreed budget for the laboratory. Any additional work is fee based and requires separate agreements[4].

Improving process management

Historically, the field of forensic science is a collection of communities of craftsmen and highly educated experts in a large number of different fields. Forensic laboratories often contain many different forensic disciplines (more than 30 at the NFI) and sometimes tend to resemble a collection of fiefdoms. Deep interdisciplinary cooperation is relatively rare, and individualism is an often-dysfunctional part of the culture. Practitioners in the field of forensic

[4] For jurisdictions in which the implementation of fee structures is simply not an available option, the creation of service level agreements can still be one of the most effective ways to manage supply and demand. Nevertheless, in order to link service levels (supply) and budgets, one still needs a way to calculate the cost of the services delivered.

science are highly committed, closely focused on the content and quality of their work and, in general, not particularly interested in process management, efficiency, delivery times, costs, or other matters of this nature. Because of this, process optimization has been somewhat neglected, resulting in practices that are often less efficient than they should be.

By applying modern process redesign methods, spectacular progress can be made towards faster delivery times, higher productivity, and lower costs. Process redesign can also help with backlog reduction. Many of these methods are data-driven and quantitative, which means that natural scientists and engineers can relate to the methodology. To restructure and improve the processes at the NFI, the methodology known as "Lean Six Sigma" [5] has been introduced. A large number of employees (up to a third of the total workforce) were trained in basic or advanced process redesign skills, so that process management became part of the culture and vocabulary of the organization, rather than an unpopular instrument imposed by management.

Creating faster technologies

Many forensic laboratories are not active in R&D or product development, while those that are tend to focus on exploring scientific matters or improving existing techniques. R&D specifically aimed at faster production is relatively rare. Nevertheless, significant gains can be made by refocusing R&D more closely on techniques and methods that will accelerate processing.

Experiences at the NFI

Like many other forensic institutes around the world, the NFI used to have a significant backlog problem. However, the organization has now successfully implemented a number of the measures described above, with the result

[5] Michael L. George, *Lean Six Sigma: Combining Six Sigma Quality with Lean Speed*, McGraw-Hill Osbourne Media, 2002

that the backlog has been eliminated. The following section describes three of these measures in more detail: introducing Service Level Agreements (SLAs) with customers; process redesign to streamline production; and refocusing R&D activities to focus on speed.

Introducing SLAs with customers

The first strategic measure implemented by the NFI was to introduce an annual SLA with its two main customers (the police and the prosecution service). This is a formal document defining the working relationship between the NFI and the customer, and specifying the number of investigations the NFI will carry out for that specific customer over a period of one year.

An important advantage of an SLA is that it forces customers to prioritize. Some people in the field implicitly believe that prioritizing among investigations is unethical, as being somehow incompatible with the notion that Justice should be blind. Nevertheless, even if justice is blind and all cases are equally important, the same cannot be said of forensic investigations if they are considered in the specific contexts of the cases in which they arise. A forensic investigation that is crucial in case *A* may be unnecessary in case *B*. Furthermore, the fact remains that the capacity of a forensic laboratory is limited, and any work that is assigned beyond that level will, under a "no-prioritization policy", simply increase the backlog and extend delivery times. In practice, it is impossible to avoid prioritization: if the customer does not do so explicitly, it will be done implicitly and therefore ad hoc. Work will be de facto prioritized on the basis of "first come, first served". From the point of view of the public good and society's needs, this is surely a situation that is far from ideal.

The SLA makes it clear that resources are limited, and that intelligent prioritization is required. Prioritization of investigations is the responsibility of the customer, as the customer is naturally most familiar with the various cases and the relative urgency of the forensic investigations being

considered. In practice, this is performed, when necessary, by liaison officers of the main customers. The step from capacity to budgets is made by modern cost accounting methods, such as *Activity-Based Costing,* which allows the organization to calculate the costs of individual investigations. In the Netherlands, the total "fee" for the work specified in the SLA is paid by the Dutch Ministry of Security and Justice, which also owns the NFI.

The SLA, which is "renegotiated" annually, prevents the accumulation of a backlog, and gives the customer an opportunity to stipulate requirements regarding important issues such as quality, logistics, and communication. This mutual formalization of the relationship gives both parties a better understanding of what is required, what they can expect and what is attainable. At first there was considerable pushback regarding the idea of introducing an SLA. However, once the logic was internalized and the advantages became apparent, it became an accepted and valuable instrument to improve a system that had created a backlog of 18,000 cases, and which had led to many instances of friction because of unclear mutual expectations.

Customers whose investigations are not paid for by the Ministry of Security and Justice pay a fee for the products or services they require. Furthermore, if the police or the prosecution request more investigations than are covered by the SLA, they pay for the additional work out of their own funds. The extra revenue that the NFI generates in this way is transparently re-invested in additional capacity and R&D. In this way, a strong link between supply (capacity) and demand is maintained.

Streamlining production through process redesign

The second strategic measure introduced was a determined effort to improve process management at the NFI. As mentioned above, the Lean Six Sigma methodology was borrowed from industry and applied to eliminate waste of various kinds, including lost hours in the production processes. This made it possible to identify the variables that are critical to achieving the

required speed and quality. Based on insights from this methodology, the NFI redesigned its processes, eliminating waiting time and economizing wherever possible to promote efficiency and speed.

The first step was to redesign processes to reduce “dead time”—i.e., time that a case spends at the NFI but during which it is not being processed in any way. Rigorous analysis of every group at the NFI showed that the time spent conducting investigations was only a fraction of total delivery time. Throughout the remaining period, the investigation was simply in a state of suspended animation, waiting for the next step in the process to begin.

At first, there was some pushback to the effort to redesign the production processes at the NFI. Some professionals tend to distrust or even resent the idea of process management. Motivated by their profession and the content of their work, they fear that shortening delivery times will have a negative effect on quality. However, as the primary focus was on eliminating “dead time”, no credible argument could be made that process redesign would have a negative effect on quality. And in fact, no such effect was observed.

Another concern was that process redesign would turn highly qualified employees into “assets” on a production line, who would carry out a limited set of standard tasks. In some cases, this may be a result of process redesign—especially when standardization is the solution to a particular problem. The current culture in many laboratories of journeymen forensic scientists involves taking cases sequentially “from crime scene all the way to the courtroom”. In many cases this model is highly inefficient and unnecessary. Often the efficiency and throughput can be increased markedly by introducing a division of labor and some type of “assembly line” operations. Not all processes can be restructured in this way, but many can. Some forensic scientists may be concerned that a division of labor will make their work less interesting, or that they will not be able to control the (quality of the) whole process personally. The claim that quality necessarily suffers from this type of process redesign is unjustified. Nonetheless, a division of

labor does have an impact on the way people work and on the content of their work. In some cases, job descriptions need to be reconciled with the appropriate level of education and qualifications required for the new jobs. Ph.D.'s are not required for conducting some of the jobs with highly standardized or repetitive tasks. Failure to redesign the processes could result in failure to achieve the appropriate efficiencies, which is not a realistic option in the long run, but failure to redefine the job descriptions could demoralize highly qualified forensic scientists because of a mismatch between expectations and requirements.

Refocusing R&D

The third strategic measure taken by the NFI to combat backlogs and long delivery times was to refocus its R&D efforts on finding innovative ways of increasing the speed of forensic processes. The NFI examined its own activities in R&D and concluded that these activities lacked a clear focus. Even though delivery times were the main concern of the customers, almost none of the R&D projects in the organization were aimed at creating technologies or methods to shorten them. Clearly, this had to change.

Looking at the whole range of R&D activities relating to forensics, three main categories could be discerned: basic research, applied research and product development. From the NFI's point of view, it was considered that basic research activities were best pursued in cooperation with universities and other partners, or left to them entirely. The NFI has been instrumental in setting up such a pure research program in The Netherlands, funded by the national science foundation (NWO)[6]. Furthermore, we believe that improvement of the scientific underpinning and objectivity of forensic investigations would clearly benefit from a larger-scale, international effort. For this reason, the NFI has been seeking partners abroad, particularly in Europe and the United States.

[6] NWO is the Netherlands Organization for Scientific Research

The type of R&D that could most fruitfully be pursued by the NFI and other forensic service providers was the development of products and services, as this would fit in well with its chosen focus on customer needs. To guide innovation in this area, the NFI adopted the concepts of "Co-creation" and "Lean Innovation." These methods stress intensive cooperation and interaction between customer and provider in the innovation process. In this way, the R&D process is steered towards the innovations with the highest value for the customer. An example of a service that the NFI developed in this way was "DNA 6 hours." Inspired by the customer's need for speed in the delivery of results, this methodology guarantees that the customer receives a report on a crime scene DNA sample, including the results of a comparison with the DNA database, within 6 hours. In practice, however, the turnaround time is generally much shorter, at approximately 3.5 hours. Taking this idea further, the NFI has also introduced a "sprint portfolio": a set of very fast versions of the usual services provided by the NFI.

Results

Implementation of these three strategic measures has resulted in the elimination of the 2007 backlog of 18,000 cases (approximately 70,000 forensic investigations) and a remarkable decline in the average delivery time at the NFI. In 2007, average delivery time was approximately 140 days. This includes both "routine" investigations as well as highly complicated customized and interdisciplinary investigations. At the end of 2012, this number had fallen to 13.8 days, and it is still falling. This represents a reduction of the delivery time of more than 90 percent. Furthermore, "customer satisfaction" (which is measured every two years by an independent agency) has increased markedly, and is now at the same level as customer satisfaction at private companies in other sectors.

3. Defragmentation

Because of the relatively recent origins of forensic science and the institutional structure in which it arose, the field is fragmented. It is fragmented in the sense that it consists of dozens of different areas of expertise that rarely engage in deep interdisciplinary cooperation. The focus tends to be on areas of expertise, and on experts, rather than on providing integrated information services to customers. Furthermore, the field of forensic science is also fragmented because most forensic laboratories only serve the geographical jurisdiction of their main customer. In most cases, they only have one or two customers (e.g., the local police force or prosecutor's office), which is partly caused by the fact that forensic labs in many cases are part of the main customer they serve. As a result, the field of forensics has developed into a sector comprising a large number of relatively small and local laboratories that necessarily act as pure production units. As an example, in the United States, much as in Europe, we find over 400 publicly funded forensic labs employing around 13,000 employees. Forensics still is a rather local affair. This is changing however.

No intrinsic borders

Forensic science and services are not intrinsically bound by jurisdictions or even national borders. In principle, therefore, there is nothing to prevent consolidation, collaboration, and cross-jurisdictional or even cross-border traffic of technology and services. Today, the fragmented condition of the forensic science sector remains largely intact, but as the field continues to grow and innovate, it is inevitable that some forensic service providers will develop their own specialist capabilities, creating an irresistible stimulus for cross-jurisdictional traffic in forensic products and services. It would be unrealistic to assume that all local forensic laboratories, especially the smaller ones, would be able to provide state-of-the-art services across the full range of disciplines. Furthermore, they cannot be expected to have sufficient critical mass to ensure continuity and quality, or sufficient

resources to support proprietary R&D programs. The reality is that most of them will remain pure production units in a limited number of forensic disciplines, containing small and vulnerable expert groups depending on just a few key people. Also, budgetary constraints, especially in an economic downturn such as we are experiencing now, will continue to put pressure on the forensic sector to produce more efficiently. Fragmentation costs money, because it cannot capture economies of scale and leads to suboptimal allocation and exploitation of what is essentially a very scarce resource.

More generally, the relatively small size of many laboratories, combined with the fact that they usually serve only one jurisdiction and operate solely within the criminal justice system, constitutes a significant and unnecessary impediment to the development of the field as a whole. This is true in relation to scientific knowledge and technology, and in relation to operational efficiency. For example, investments in equipment or R&D that may not make sense on a local level—because of insufficient caseload—may be justifiable on a regional or even global level. Similarly, such investments may make even more sense if the forensic laboratory is allowed to broaden its customer base, thus expanding the caseload still further and creating critical mass. Inevitably, setting up a modern forensic laboratory is an expensive business, due in part to the infrastructure required. Some disciplines are more expensive than others, but where, in particular, the fixed costs are high, significant economies of scale can be achieved as the size of the caseload increases. In other words, the fragmentation into many relatively small production units is inefficient, leads to vulnerabilities, contributes to the backlog problem, and is an obstacle to the kind of research and innovation that would propel the field forward.

Capacity problems

As stated above, forensic science is not a unified field, but rather a collection of specialist disciplines. At the NFI, for instance, more than 30 separate disciplines exist. Some of them are staffed by just a few experts, as the caseload is not large enough to justify additional staff. Consider just such a

small discipline, staffed by three qualified forensic examiners. If one of them falls ill, attends a training course or leaves the organization, this will have a considerable impact on available capacity. Although such fluctuations in themselves pose considerable organizational problems and contribute to the growth of backlogs, the trouble they cause is, of course, compounded by the inevitable and unpredictable fluctuations in the inflow of cases. In addition, suppose the organization wishes to spend about 10 percent of its capacity on R&D in this field. In a team of three examiners, this amounts to 0.3 full-time equivalents: in other words, these examiners, either jointly or individually, can at best devote only a small portion of their work time to innovation. However, in the real world, the caseload is such that it will tend to drown out the R&D, with the result that no significant R&D effort is achieved at all. The result is stagnation of the field.

If the forensic laboratory could service a much larger geographical area and a larger number of customers, then the caseload at a certain point would become sufficient to support a staff with critical mass. If there are 10 or 20 qualified forensic examiners in the discipline in question, for instance, one or two of them could be freed up to conduct research full-time. Furthermore, a larger staff has much more flexibility to deal with setbacks such as illness. In short, the current fragmentation of the forensics sector, with its many, relatively small, laboratories, is not conducive to R&D, and gives rise to problems relating to flexibility and continuity.

Some might argue that the lack of R&D could be solved by creating a centralized system of R&D-oriented institutes, possibly at universities or other institutions. These would then perform most of the research. The theory is that this research would subsequently diffuse into the forensic system. There are reasons why a certain amount of skepticism towards this approach is justified. Experience shows that a severe disconnect is likely to arise between the central research institutes and the hundreds of production units doing all the casework. After all, even integrated technology companies find it a struggle to maintain an R&D program that accurately and

continuously reflects their customers' needs. If (independent) research institutes are so far removed from actual casework and from customers, it will be very difficult to keep them on the right track. The probable outcome would be research that is very clever, but not necessarily what customers want or need. Customer needs are often surprising, as the NFI (and many companies in the private sector) have learned the hard way. In order to be able to appreciate customers' needs, it is necessary to remain in close contact with them and/or with those who will use the information provided by the investigations in question.

The foregoing suggests that it is forensic institutes themselves that are best placed to carry out R&D programs, alone or with partners. This, at least, provides some guarantee that results will be of the highest value to customers. However, in order for the institutes to be able to support significant R&D programs, to guarantee continuity and to capitalize on economies of scale, they need to create critical mass. This can be achieved by consolidation (fewer and larger institutions), by specialization, or by broadening their customer base to cover all government agencies that have a forensic need.

4. A growing need for training and education

As mentioned above, forensic investigations are becoming increasingly important and "mission critical" to customers. At the same time, forensic science and technology are becoming more complicated and difficult to understand for the layman. This constitutes one of the fundamental challenges of the field. For almost everyone, a suspect's confession is much easier to understand than, for example, the evidential value of a complex chemical analysis. Nevertheless, the latter may provide a much higher evidential value. Furthermore, using forensic investigations correctly, in a non-biased way, and interpreting results as intended, is not as easy as it may seem.

All this points to a growing need for training and education. This applies not only to forensic investigators, but even more so to the users of forensic information. This is largely due to a change in the whole process of criminal investigation. In a sense, the role forensics plays is similar to automation in factories: it “technologizes” the production process in criminal investigations. In manufacturing, the nature of the “human factor” has changed. Manual labor has been partially replaced by technology (machines) and knowledge workers (who design, create, and program the machines). Similarly, traditional labor-intensive investigative methods are being replaced or complemented by forensic science and technology. But this means that all the stakeholders in this process need to be trained to deal with this new situation. Police officers, prosecutors, and judges, for instance, need to know how to use forensics properly: they need to ask the right questions, and they need to interpret forensic results correctly.

Several years ago, in line with the need for more education and training, the NFI set up its own Academy with the express purpose of providing a wide range of stakeholders with the forensic knowledge and skills they need for their work. These stakeholders include forensic investigators, judges, police officers, first-responders, policy makers, and lawyers. Although each group has different requirements, the general aim is to train them to collect traces correctly (and not destroy important traces), to use forensic laboratories effectively (and ask the right questions), and to interpret the results of forensic investigations correctly. The NFI Academy has been a huge success, providing approximately 10,000 person-days of training in 2012 for interested practitioners from around the world.

5. An integrated model

Over the past few years, the NFI has implemented (and indeed is still implementing) an “integrated” organization model based on the analysis and principles presented above. This means that the organization not only

provides forensic services to (domestic and foreign) government agencies, but that it also performs its own research and development in order to improve its services and create innovative new ones. In its R&D effort, the NFI cooperates with many companies, universities, and knowledge institutes around the world, especially in the Netherlands, Japan, and the United States. The R&D is partially financed by the fee received from customers who pay for the services of the NFI. The fact that the NFI can and does deliver products and services to government agencies in the Netherlands and abroad, as well as to intergovernmental organizations, is also part of the integrated model.

Forensic products and tools

The NFI still conducts many standardized “commodity” services. The organization also takes on a large and growing amount of custom work. This type of work often leads to specialized high-end products and tools, because examiners need them to do their cases. This may take the form of both hardware and software. Subsequently, such products and tools can be made available to the forensic community at large, to beneficial effect. However, the benefit goes beyond the immediate use of the product or tool. The revenues so earned are invested in new R&D to enhance current forensic capabilities and investigation techniques. If many integrated forensic institutes around the world were to do the same, this would create a whole new dynamic in the field. Conversely, if innovative products and tools that require large investments in R&D were distributed free of charge, this would only mean that funds to fuel the innovation engine would become depleted, stopping further innovation in its tracks. Laboratories that do not invest in R&D would benefit from the investments of others, who would subsequently become starved of funds themselves. Clearly, that is not a sustainable model for innovation, and it would perpetuate the situation in which most forensic laboratories are mere production units.

Concluding remarks

Forensic science is clearly at an important stage in its development. New advances in technology have placed forensics in an accelerating cycle of growth, as a wider range of parties than ever before comes to realize just how useful forensics can be for their own purposes. But this popularity—gratifying as it may be—nonetheless brings its own challenges, as laboratories become bogged down in work and customers become more demanding. This paper has reviewed some of the practical problems that the sector will need to resolve if it is to meet the demands of society: understanding what customers need, increasing the value of the information we provide to them, and generally accelerating our operations. More profoundly, however, we will need to undergo a shift in mindset and governance.

Several years ago, the NFI saw itself faced with these challenges and, in response, developed and implemented a number of measures that have enabled it to eliminate its backlogs and dramatically improve the quality and delivery times of its forensic investigations. In this way, it has been able to markedly improve customer satisfaction and has shown that its integrated model is a viable way forward. The forensic sector has great potential, but it will certainly find itself challenged to live up to the high expectations that customers and society have of it. It is equally certain that the sector can only succeed if it takes up the challenge and makes fundamental changes where necessary.

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