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Benchmarking forensic volume crime performance in Australia between 2011 and 2015

Eva Bruenisholz [a], Nicholas Vandenberg [a], Cheryl Brown [b], Linzi Wilson-Wilde [a, *]

[a] National Institute of Forensic Science, Australia New Zealand Policing Advisory Agency, 637 Flinders Street, Melbourne, 3008, Australia
[b] Forensic Service Branch, South Australia Police, 60 Wakefield Street, Adelaide, 5000, Australia

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ABSTRACT

In 2011, the Australia New Zealand Policing Advisory Agency National Institute of Forensic Science Australia New Zealand (ANZPAA NIFS) ran the End to End Forensic Identification Process Project: Phase 1 (E2E1) to identify bottlenecks and inefficiencies across the end-to-end forensic process in Australia and make recommendations as to how these might be addressed. The study concentrated on the analysis of DNA and fingerprint evidence in burglary offences, benchmarking current forensic processes and performance across all eight Australian States and Territories (jurisdictions). Following a positive response, overwhelming support was given for the project to be repeated four years later in order to measure any improvements. End to End Phase 2 (E2E2) was conducted in the same eight Australian jurisdictions with the same sampling areas, across the same length of time as E2E1. The aim was to enable agencies to compare their own data from the previous phase and establish, amongst other things, whether implemented recommendations from E2E1 project had any significant impact. Data was collected for over 7,500 burglaries nationally. This paper presents the findings of the 2015 study as well as comparative analyses between 2011 and 2015. Finally, we discuss the measures taken, whether legal, technological or organisational, that are likely contributors to the performance improvements.
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1. Introduction

For almost two decades, forensic science has been under increased scrutiny with criticisms raised in two main areas: the fundamentals of forensic science [1,2] and its value [3–10]. Recent economic constraints and ever shrinking budgets have contributed to a stronger emphasis on the value of forensic science [11,12]. The global financial situation has resulted in a government focus on resource savings and cost reduction, leading to a need for forensic service providers to reduce costs whilst still delivering high quality forensic services. This imperative to improve and increase services while simultaneously reducing turnaround times and costs has impacted all laboratories internationally [13]. The closure of the Forensic Science Service in the United Kingdom in 2012 [13] was an extreme example of this and how, in some models, forensic service providers are expected to make a profit [14].

There can be a perception that forensic science is the answer to solving all crime. However it was found that only a small proportion of cases involving forensic evidence resulted in an arrest or trial [15,16]. Whilst Roman et al found that the introduction of DNA analysis to property crime investigation increased the identification of suspects by 18%, increased arrests by 12% and doubled the number of cases progressing to prosecution [17,18]. Criticisms of forensic service provision include the cost and lengthy turnaround times, where delayed results become ineffective in assisting police to solve and prevent crime. Therefore, understanding the value of forensic science and how it can best fit within the broader policing context is a challenge for the forensic science community [19].

Firstly, the word 'value' is ambiguous and is often not understood. Value seems to be linked with effectiveness and efficiency, however these words also appear to have various meanings and are even used interchangeably. Ludwig [8] cites Drucker who defines effectiveness as "the measure of the impact or the ability to achieve the desired outcome without wasting resources, energy, time or money". Efficiency on the other hand is the "measure of productivity, or the degree to which something is successful in producing a desired result". Bitzer defines efficiency as "doing things right" and effectiveness as "doing the right things" [6] pp. 511. Adding value could then be summed up as "doing the right thing right" [6] pp. 511.

Secondly, in order to discuss and estimate the value of forensic

* Corresponding author. ANZPAA National Institute of Forensic Science, 637 Flinders Street, Docklands, Victoria, 3008, Australia.
E-mail address: linzi.wilson-wilde.nifs@anzpaa.org.au (L. Wilson-Wilde).

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science, it is important to understand what forensic science can contribute within the context of law enforcement expectations [20]. This means establishing what the desired outcome is. Unfortunately, the answer to this question is not straightforward. Indeed, the various agencies and stakeholders in the criminal justice system that utilise forensic science services have varying expectations and needs [8]. Studies have demonstrated a return on investment by utilising forensic science services [21–23]. Additionally, value should include the impact of deterrence in reducing recidivism, which includes subsequent societal benefits [17,18,24,25].

Conscious of the criticisms, and despite these uncertainties, forensic service providers have identified that they need to adapt to these economic constraints and modify and improve their service delivery. Service providers are constantly working to streamline their processes and deliver results more quickly to their stakeholders [26,27]. This is done in various ways; two of which are relevant here: staff recruitment and process improvements.

The quality of crime scene investigation work influences the value of the whole process [28] and studies have been conducted to determine if the value of forensic science could be improved through targeted recruitment of people with the skills specifically needed for the task [29–31].

The other approach has been for forensic services to measure their performance, either through benchmarking against other forensic service providers and learning from best performers [15,32–37], or through revising their business models, including privatisation or the implementation of a LEAN approach [12,27,38–44].

In this context, in 2011, the Australia New Zealand Policing Advisory Agency National Institute of Forensic Science Australia New Zealand (ANZPAA NIFS) facilitated the End to End Forensic Identification Process Project: Phase 1 (E2E1) [16]. Considering that the true impact of the work of forensic science is unknown [3], the aims of E2E1 were to "develop a framework to capture and compare data, to develop a simple performance management model and to develop a national model for the process that would support maximum efficiency and effectiveness" [15]. The study benchmarked current forensic processes and performance across eight Australian States and Territories (jurisdictions) and concentrated on burglary offences and the analysis of DNA and fingerprint evidence. The study was conducted within the policing context investigating cases moving from policing into the forensic process and back out to policing. The project resulted in the identification of bottlenecks and inefficiencies across the entire end-to-end forensic process in Australia and made recommendations as to how these might be addressed.

Following a positive response from the government service providers of Australia, overwhelming support was given for the project to be repeated four years later in order to measure any improvements and lessons learnt. The repeat project, End to End Phase 2 (E2E2), was conducted in the same eight Australian jurisdictions in the same sampling areas and length of time as E2E1, aiming to enable agencies to compare their own data from the previous phase and establish, amongst other things, whether recommendations drawn from best performers of the E2E1 project had any significant impact.

This paper presents the findings of the 2015 study as well as comparative analyses between 2011 and 2015. Finally, we discuss the measures taken, whether legal, technological or organisational, that are likely contributors to the performance improvements.

2. Data collection and analysis methodology

Data collection and analysis followed the approach adopted in the original End-to-End project [15]. Data from 7,591 non-aggravated residential and non-residential burglary cases were collected in eight Australian jurisdictions (a combination of government forensic laboratories from police and non-police agencies) from cases identified though 17 police stations (10 metropolitan and seven regional sites) from May to September 2015. Six jurisdictions nominated one metropolitan and one regional police station, one small jurisdiction nominated one metropolitan station only and one large jurisdiction was able to nominate three metropolitan stations in addition to the regional station.

The study concentrated on the analysis of DNA and fingerprint evidence collected. Data were transmitted monthly via a standardised Excel spread sheet requiring date/time entries (dd/mm/yyyy hh:min) and information on the progress of the case regarding the fingerprint and DNA evidence. A follow-up time of three months (until December 2015) was added to allow for cases to progress as far as possible through the stages. Data quality checks were conducted manually to identify and correct any inconstancies.

Mirroring the first study, the primary measures of efficiency and effectiveness were the lead-time and success rate at each stage. Lead-time was determined through the collection of date/time entries for defined points within the five following stages based on the Scientific Work Improvement Model (SWIM) study [37] (Fig. 1):

1. Crime scene attendance
2. Evidence submission
3. Analysis of evidence
4. Identification
5. Arrest

Lead-time was defined as the time taken for a case to progress through one stage to another and ultimately the total time taken to move from the beginning of Stage 1 to the end of Stage 5. The unit of measure was days for each stage, except for Stage 1, which was measured in hours.

Success at each stage was defined separately for each evidence type (fingerprint or DNA and overall). Overall success was considered within the policing context that the forensic services are applied and was therefore defined as the arrest or charging of a suspect. Whilst this has issues in linking the forensic services with an outcome, it was determined that this was suitable given the policing overlay of this project. The unit of observation for this study was a case, not an offender. Two or more arrests based on forensic evidence from one burglary scene, were counted as one successful unit.

Once all data analyses were conducted, a jurisdictional survey including comparative data was sent to each jurisdiction seeking information and possible explanations for any substantial variations detected (increase or decrease). The survey provided the ability to capture further information identifying opportunities to improve the efficiency and effectiveness of the forensic processes. This also assisted in providing organisational context and nuance in support of the project findings.

3. Data analysis - key findings

Results are presented in the overall context of all cases, breaking these down into those that examined fingerprint evidence versus DNA evidence and comparing results from 2011 and 2015. Results are also provided for each of the eight jurisdictions and compared to each other, as well as their performance differential between 2011 and 2015. Finally the national performance is described to illustrate the impact of process improvements or changes as a result of the 2011 study.

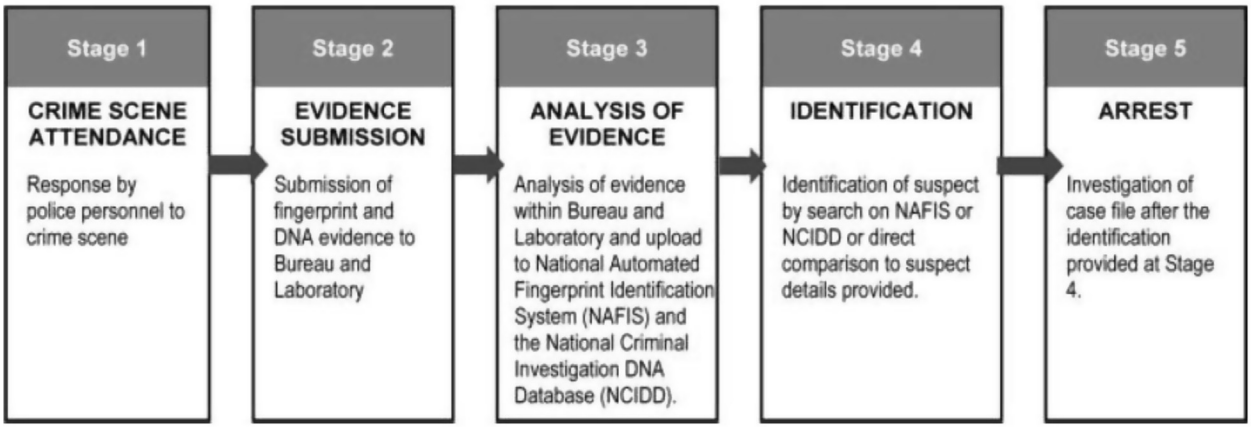

Fig. 1. Overview of the five analysis stages for the data collection time points [15].

3.1. Overall results from 2015

From the results of all cases and those examining fingerprint and DNA evidence, the following can be summarised:

- 76% of burglaries reported to police were attended by a crime scene investigator with a median response time of 3.5 h and a median time spent at the scene of 44 min;
- Forensic evidence was submitted for analysis in 39% of crime scenes attended;
- There were twice as many cases with fingerprint evidence submitted compared to DNA (32% vs. 14%);
- Almost 35% of forensic evidence analysed resulted in an identification;
- Identification rates were the same for both fingerprints and DNA (32%);
- The overall arrest rate after forensic identification is 4.53%.
- There was a similar arrest rate as a result of identification for fingerprint and DNA evidence (41% vs. 42%);
- In 3.2% of burglary crimes reported to the police, an arrest was made based on fingerprint identification (243 arrests), compared to 1.5% for arrests based on DNA identifications (111 arrests);
- Lead times are significantly shorter for fingerprint evidence than DNA, regardless of the stage. This resulted in a median overall end to end process time of 16 days for arrests based on fingerprint identification compared to 49 days for arrests based on DNA identifications only;
- In every jurisdiction, the longest lead-time was observed at the last stage of the process, from identification to arrest.

The data (Table 1) illustrates a continuous and significant reduction in the number of cases progressing through each of the stages and that forensic information from fingerprints and DNA has an impact in progressing to an arrest in a relatively small number of burglary cases. The data also illustrates that a majority of the time taken in the investigation of a case is spent following up on forensic information.

3.2. National comparison of 2011 and 2015 results

The results of the 2011 and 2015 studies were compared firstly on a national scale. Table 1 presents a comparison of the rate of progression through the stages, of which the following points can be highlighted:

- Although the number of crimes reported decreased between 2011 and 2015, there is an increase at every other stage of the process in 2015. More cases were attended, submitted and analysed, leading to more identifications and arrests. The overall end-to-end arrest rate has almost doubled between 2011 and 2015 (from 2.4% to 4.7%);
- The overall number of cases attended increased by 6% (from 70% to 76%) although four jurisdictions increased their response and four jurisdictions decreased their response;
- Almost 35% of forensic evidence analysed resulted in an identification (an increase from 25%);
- Fingerprint evidence continued to be more frequently analysed than DNA, with submission rates for both increasing by 4% between 2011 and 2015. However, proportionally more arrests were made from DNA identifications in 2011 (50% compared to 37% for fingerprint evidence) than in 2015 (42% and 41% respectively);
- Identification rates increased for both fingerprints and DNA from 23% to 32%;
- The proportion of arrests linked to forensic evidence has increased, from 3.5 per 100 burglaries attended to 5.8 per 100 in 2015.

Table 1
Number and percentage of cases progressing through the five stages of the study.

	Cases		Reported	Attendance	Submission	Analysis	Identification	Arrest	End to End
Progression	**All cases**	**2011**	8179	5691 (70%)	1861 (33%)	1850 (99%)	459 (25%)	199 (43%)	2.4%
		2015	7591	5802 (76%)	2248 (39%)	2248 (100%)	779 (35%)	344 (44%)	4.53%
	Fingerprints	**2011**			1569 (28%)	1564 (99%)	362 (23%)	135 (37%)	1.6%
		2015			1846 (32%)	1846 (100%)	586 (32%)	243 (41%)	3.2%
	DNA	**2011**			581 (10%)	571 (98%)	134 (23%)	67 (50%)	0.8%
		2015			833 (14%)	832 (99%)	267 (32%)	111 (42%)	1.5%

Note: % in brackets indicates the cases as a percentage of the previous stage.

Table 2
Lead-times (median) of cases through the five stages of the study, overall and according to the evidence type.

	Cases		Attendance time	Submission time (days)	Analysis time (days)	Identification time (days)	Arrest time (days)	End to End time (days)
Lead time	**All cases**	**2011**	4 h (30 m at scene)	1	1	1	14	29
		2015	3.5 h (44 m at scene)	0	1	3	5	28
	Fingerprints	**2011**		Same day	1	Same day	11	19
		2015		Same day	1	1	6	16
	DNA	**2011**		5	3	15	20	49
		2015		6	3	20	11	49

A comparison of the 2011 and 2015 data demonstrates an improved use of forensic evidence, with more evidence submitted and analysed, leading to an increase in the arrest rate. This highlights the benefit of the effective use of forensic evidence. However, the effectiveness of forensic science is also determined by efficiency and process times, ensuring forensic information is provided in a timely manner.

Table 2 details the lead times, which represent the median time taken to move from the previous stage to completion of the listed stage. Results for all cases are then broken down to those cases involved fingerprints and DNA and comparing the 2011 and 2015 data. End to end figures only include those cases for which an arrest has been made. The results illustrate the following:

- Overall end-to-end lead-times remained similar between 2011 and 2015 for all cases (reduced by one day), DNA (remained at 49 days) and fingerprints (reduced by three days).
- Longer submission and identification lead times for DNA contribute to the longer overall lead times for DNA.

Within the forensic facility, turnaround times for fingerprints are relatively short, whereas in comparison, DNA turnaround times are much longer. Submission times for DNA are longer than anticipated and have increased by a day since 2011. Identification lead time has also increased, but this is offset by a faster follow up identifying suspects once the identification has been provided to police.

The overall results demonstrate the usefulness of forensic science, where evidence is submitted to the forensic facility, by providing information (an identification) to police in 35% of cases and of those cases submitted to a forensic facility, 15% will result in an arrest. However, the picture is slightly different when looking at individual jurisdictions.

3c. *Jurisdictional comparisons of 2011 and 2015 results*

The results illustrated large differences between the jurisdictions in their ability to progress between the stages, as well as the overall turnaround times. A comparison of the individual jurisdictional response rates is presented in Table 3a (attendance to analysis) and Table 3b (identification to arrest). Key findings in response rate from attendance to arrest are:

- There are substantial variations between jurisdictions in the number of cases reported in 2011 and 2015 ranging from an increase of up to 131% to a decrease of 51% (Table 3a);
- The variation of the attendance rate shows that some jurisdictions increased their response up to 56% while some decreased it up to 15% less (Table 3a);
- The rate of submission varies from an increase of 32% to a decrease of 12% (Table 3a);
- The rate of analysis remained close to 100% of submitted exhibits (Table 3a);
- The identification rate varies between an increase up to 50% and a slight decrease of 3% (Table 3b);
- The proportional arrest rate to the number of identifications increased by up to 43% for jurisdiction F and decreased down by 16% for jurisdiction C between 2011 and 2015 (Table 3b);
- However if we compare the arrest values to the number of cases attended jurisdiction C has increased its arrest by 15% and jurisdiction F by 10% (Table 3b).

The results illustrate that jurisdictions are attending most cases reported, but there is a large variation in the amount of evidence subsequently submitted for analysis. The results demonstrate large fluctuations between the jurisdictions in case load, but a general trend towards an increasing case load for the facilities. Increasing identifications are evident, probably as an impact of increasing databases utilisation facilitating the rate improvements.

Within the jurisdictional context, the progression of cases through the forensic process is only beneficial if the information provided is within a timely manner. Lead times between the jurisdictions were found to be highly variable and this also extended to the individual stages. A comparison of the jurisdictional response times through the stages is summarised in Fig. 2. The top bar for each jurisdiction represents 2011 data and the lower bar 2015

Table 3a
Variation in rates (%) of the various stages (attendance to analysis).

	Number of cases		Rate of attendance/ reported (%)		Rate of submission/ attended (%)		Rate of analysis/ submitted (%)	
	2011	2015	2011	2015	2011	2015	2011	2015
Jurisdiction A	987	549	44	100	61	49	100	100
Jurisdiction B	1026	656	77	72	28	26	100	100
Jurisdiction C	670	588	50	54	26	58	94	100
Jurisdiction D	1006	2326	77	76	41	49	100	100
Jurisdiction E	1244	672	57	73	32	24	100	100
Jurisdiction F	305	681	70	55	81	69	97	100
Jurisdiction G	1282	1298	82	87	24	19	100	100
Jurisdiction H	1659	821	83	84	23	30	100	100

Table 3b
Variation in rates (%) of the various stages (identification to arrest).

	Rate of identification/ analysed (%)		Rate of arrest/ identification (%)		Rate of arrest/ attended (%)	
	2011	2015	2011	2015	2011	2015
Jurisdiction A	14	34	32	21	3%	3%
Jurisdiction B	23	31	39	49	3%	4%
Jurisdiction C	35	85	55	39	5%	19%
Jurisdiction D	29	28	52	43	6%	6%
Jurisdiction E	40	37	34	39	4%	3%
Jurisdiction F	25	31	37	80	7%	17%
Jurisdiction G	21	32	38	38	2%	2%
Jurisdiction H	20	27	60	59	3%	5%

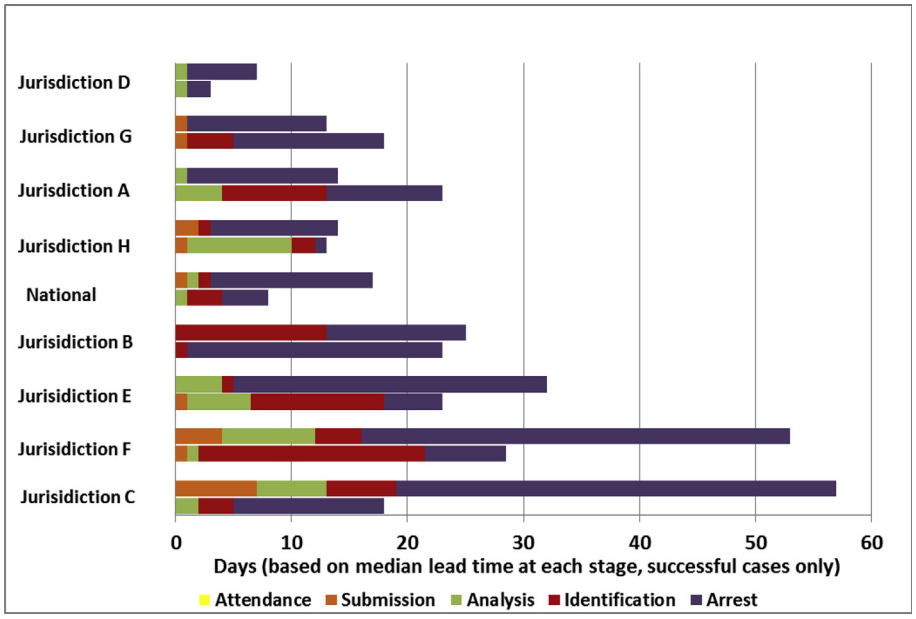

Fig. 2. 2011 and 2015 overall median lead times by Jurisdiction. N = 344.

results. Only cases resulting in an arrest are presented. National represents the aggregate across all 17 sites in the eight jurisdictions. It should be noted that the sum of the five steps does not equate to the median end to end value due to case attrition across the different stages.

From the data presented in Fig. 2 the following can be noted:

- All jurisdictions maintained a same day crime attendance;
- Submission lead-times (median) generally decreased or remained the same. One jurisdiction decreased its time from 7 to 0 days;
- Two jurisdictions decreased their analysis time, three remained the same and three increased;
- The median identification lead-time decreased by up to 12 days while increasing by up to 16 days for another jurisdiction;
- The arrest lead-time decreased for all but one jurisdiction; however, this stage is by far still the longest stage of the end-to-end process;
- Generally, most jurisdictions decreased their overall lead-time by up to 39 days, representing an up to 68% decrease. However, two jurisdictions increased their turnaround times and one jurisdiction's lead-time increased by 64% compared to 2011.

Fig. 2 illustrates the significant variation in turnaround times between the jurisdictions with four jurisdictions able to provide information to police in five days or less, three less than 20 days and one just over 20 days. However, the national result to provide an identification remains less than five days. Importantly, the biggest median lead times occur outside of forensic facilities in the arrest stage, however there are clear reasons why this is the case (location of suspect, case load etc.).

To further illustrate the differences between the 2011 and 2015 results, the overall end-to-end effectiveness as calculated by the arrest rate (percentage of arrests per 100 crimes reported) was plotted against the end-to-end efficiency as calculated by the median lead times (in days) by jurisdiction.

The top right quadrant of the graph indicates best performance in both dimensions (fast with high arrest rate), the top left indicates a slow lead time with a high arrest rate. The bottom left quadrant indicates a slow lead-time with a low arrest rate (worst quadrant). Finally, the bottom right quadrant indicates a fast lead-time with a low arrest rate. It also should be noted that due to the attrition of cases across the stages, these jurisdictional effectiveness versus efficiency results represent the analysis of relatively small datasets.

By reviewing the overall performance of each jurisdiction for 2011 and 2015 (Fig. 3), the following can be noted:

- All jurisdictions have improved in some ways, either in effectiveness or in efficiency;
- Jurisdiction F and C achieved significant improvements in both lead times and arrest rates;
- There is no consistent correlation between end-to-end effectiveness (arrest rates) and end-to-end efficiency (lead time). The jurisdictions with the fastest lead times are not necessarily the ones with the highest arrests.

From an overall forensic performance perspective, the top performer is Jurisdiction D, as it was in 2011. However, this does depend on what the important metric is. If arrest rate is the most important factor, regardless of time taken, then jurisdiction C (closely followed by jurisdiction F) is the top performer. Regardless, the results demonstrate the application of learnings from the 2011 project have improved the overall end-to-end performances by the jurisdictions.

4. Jurisdictional surveys - key findings

Given the complexity of the end-to-end forensic process and the differences between the 2011 and 2015 data, both in the overall performance of the jurisdictions and also the performance between stages within the jurisdictions, a survey was distributed to jurisdictions to identify what measures could explain the improved performances observed. This section compiles these changes and presents them for the following four stages studied: crime reported and attended, evidence submission, evidence analysis and identification. No information is presented for the arrest stage, as forensic service providers usually have no influence over that stage.

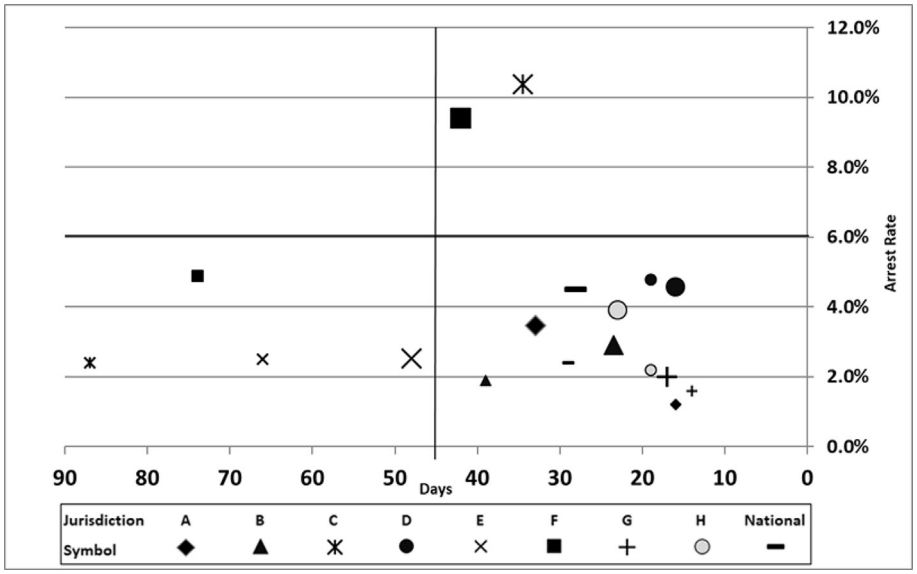

Fig. 3. End-to-end effectiveness (arrest rates) against end-to-end efficiency (median lead-time) per 100 crimes reported by jurisdiction – 2011 (small symbol) vs 2015 (large symbol).

4.1. Stage 1: crime reported and crime scene attendance

The number of cases reported changed substantially for most of the jurisdictions. Explanations ranged from a change in the boundaries of the data collection sites within jurisdictions, to a change in the level of offending. A regional boundary within Jurisdiction D was expanded to almost double in size, substantially increasing the number of cases reported. In contrast, the increase in cases for Jurisdiction F reflect a spike in the rate of burglaries attributed to a high number of known recidivist offenders being out of custody during the data collection period.

On the other hand, the reduction observed in some jurisdictions was a result of new approaches implemented. One jurisdiction underwent a structural and cultural change [26], implementing a forensic intelligence framework pilot between 2012 and 2015 leading to two main changes: an increased recovery of traces for evidence and intelligence purposes and a collaborative approach to case investigation. An improved response roster ensured scenes were attended in a timely manner and the creation of a dedicated rapid laboratory, focused on a multi-disciplinary approach which improved evidence targeting and collection. This intelligence framework approach involved a 100% response rate to scenes to harvest all evidence and intelligence with the aim of identifying case linkages [26]. This process has most likely contributed to a decrease in the number of cases reported for the jurisdiction by almost 50% between 2011 and 2015 due to the targeted arrest of recidivist offenders through the application of the forensic intelligence framework.

4.2. Stage 2: evidence submission

Improvements in the evidence submission stage were mainly due to a change in the method of evidence transmission. Digital capture of fingerprints and electronic remote submission from the scene using a secure network and ruggedized computer and the transport of evidence using tamper evident audit bags via a courier service, have led to a significant reduction in submission times. This has the added benefit of freeing up police resources for other duties, however, given the geographical size of Australia, the median lead time for DNA exhibits is still measured in days (6 days for the 2015 results).

Jurisdiction B experienced a 30% drop in cases reported while maintaining its attendance rate and improving its attendance time from 19 h to 8 h, as a result of the introduction of afternoon shifts, which better aligned expertise to the hours in which a crime is committed or identified.

The quality of exhibits submitted for analysis was also improved through an up-skilling program for scenes of crime officers (SOCO), a SOCO performance feedback mechanism and targeting exhibits with high value DNA evidence such as visible biological fluid, to increase the analysis success rates.

4.3. Stage 3: analysis of evidence

Following E2E1, most jurisdictions worked on a joint initiative between the Police and the DNA laboratories to decrease turnaround times for DNA submission, analysis and identification. These initiatives include the introduction of a sub-sampling by SOCOs into robot-ready tubes, the prioritisation of exhibits through triaging and the introduction of robotics in the DNA laboratory [45]. It is worth noting that the decrease in turnaround time occurred despite many DNA laboratories changing from 10-loci to 21-loci profiling kits, which take significantly longer to interpret. Turnaround times for DNA analysis are still lengthy in some jurisdictions illustrating an opportunity for process improvements.

Decreases in turnaround time for fingerprint identification and arrest were due to a reorganisation of team workflows to simultaneously focus on new and old cases, dedicated volume and major crime teams and the movement of the scene response capability to the SOCOs. In addition, shift work, covering 6am–2am across a 7-day week was introduced. The net result was the clearance of the case backlog in one jurisdiction in approximately 6 months.

4.4. Stage 4: identification

Low identification rates were found to be an issue in E2E1. A major reason identified was the limited collection of suspects' reference material, reducing the database size and linking potential. A change in processes to focus on this issue resulted in a 2.5 fold increase in identifications, while the overall performance

increased by 10%. However, long lead times were still found for DNA identification, potentially due to analysis and interpretation times. One jurisdiction reported that they were updating systems within their laboratory, which resulted in them being an outlier with longer analysis and identification lead times. This contributed to the increase in the DNA lead time obtained for identification involving DNA cases.

Systematic capture of tenprints using the automated Live Scan system improved tenprint quality increasing identification opportunities. One jurisdiction reduced its fingerprints identification lead-time to 29 h by extending the automated capture of fingerprints to the entire process. The capability enables rapid (within minutes) suspect generation and identifications by automating the identification using a software similar to that used during the capture of tenprints via Live Scan devices. This automated searching process is conducted against a local database, providing real time information to investigators.

The added value of this process is demonstrated through a case example: a fingerprint located at a scene was photographed and electronically uploaded. The fingerprint was automatically compared, and the name of a suspect was provided to detectives at the scene who drove to a known address and waited for the suspect, who arrived later with the stolen goods.

In situations where an identification is obtained through a fingerprint (usually the faster process) while a DNA sample is concomitantly submitted, the DNA analysis and court report is still completed leading to a duplication of effort and resources. Considering the forensic intelligence framework, it is not beneficial to stop the DNA analysis as further links to other cases could be identified. The suggested model [46] is to proceed with the analysis of both the fingerprint and DNA, with an option to halt the process after the DNA profile has been uploaded to the database and provide a DNA result notification, as opposed to a full court statement. If the DNA sample identifies the same person as the fingerprint, the DNA reporting process should stop, saving resources. If the DNA profile search identifies a different person than the fingerprint, the reporting process should continue. This also has the added benefit of ensuring DNA profiles are developed and uploaded to the DNA database. In this way the database can continue to grow and reflect the potential offending population. By identifying perpetrators early and having their profiles on the appropriate databases, it can serve as a deterrent, potentially reducing recidivism and detecting recidivism if it does occur.

5. Discussion

Overall, the results of this study revealed substantial changes at all stages in the forensic process between the 2011 and 2015 data sets. The results also illustrated a wide variation between jurisdictions across each stage, both in terms of effectiveness (percentage of cases that progress to the next stage) and efficiency (lead time taken to progress to the next stage). This is notwithstanding the limitations discussed in Brown et al. [15] regarding the analysis of a single crime type (in this study burglaries) during a defined period (set months of the year) and data collection points that are non-random (defined stages in the forensic process).

Forensic science is generally often criticised for being slow and responsible for delays in the investigation. This study illustrates that, certainly for fingerprints, analysis times are relatively quick. Indeed, similarly to 2011, the last stage, arrest, dominates the whole process, with lead-times often longer than all other stages. This may be due to the difficulties police face in locating persons of interest. It could also illustrate the disconnect between forensic and investigative priorities and differences between the investigative and evidential phases of forensic casework. The results observed reflect the need to provide the forensic results quickly. If results take months, police may have moved on to other cases.

Benchmarking performance is hindered by the challenge of collecting relevant and usable data, which is defined, recorded and analysed in the same way. This is particularly evidenced in the Foresight project [32]. Few jurisdictions have integrated forensic systems between police and the laboratory making the data collection very difficult. The survey revealed that contact officers spent up to 30 days looking through up to five independent IT systems to collect the data through the five stages. Not only is this highly time consuming, hindering the agency's ability to monitor their performance on a regular basis, but these challenges create a higher risk for data error.

On a stage-by-stage basis, from the 2015 data, there was no consistent evidence to suggest that a strong performance at one stage of the process correlated with a strong performance at another stage or that there was a link between stages. Indeed, because of the complex connectivity of evidence, potential benefits from one stage may be offset by critical weaknesses at another. Some jurisdictions increased their attendance rate, while the number of cases reported cases decreased and the number of fingerprint and DNA cases submitted remained similar to 2011. Some maintained the same attendance rate, while numbers of cases reported doubled, representing a more than twofold increase in the number of cases attended, and an up to threefold increase in the number of fingerprints or DNA cases analysed. This increased workload inevitably led to some longer lead-times. Jurisdiction D maintained its position as a top performer, largely due to integrated systems, sampling in the field using robot ready tubes and a highly automated workflow.

Finally, some jurisdictions saw a decrease at all the stages in both workload and lead-times. Jurisdiction C displayed the greatest reduction and also increased its arrest rate by 16%. This was due to the police agency creating a team to specifically target property crime between 2011 and 2015. Jurisdiction F also showed a marked improvement, directly due to the outcomes of E2E1. The reduction was largely due to retraining SOCOs with a focus on targeting better evidence, which subsequently reduced the number of extraneous samples being submitted, which decreased laboratory pressures, which in turn decreased backlogs and increased turnaround times.

Further, there remains significant variation in performance across the jurisdictions, indicating potential scope for further improvement across the many stages of the forensic process. Considering that each police agency operates under different legislation and internal practices, it is anticipated that each jurisdiction may need to tailor their strategy in order to further improve performance in processing burglary cases.

6. Conclusion

Many jurisdictions had existing performance measures in place but had not been in a position to benchmark their performance on a national basis. The E2E1 project allowed jurisdictions to reflect on their results and led to changes to improve process performance (reduce bottlenecks and waste).

Processing and analysing volume crime samples is a difficult area to make improvements in as gains from changes in any of the stages can be offset by weaknesses at another. The vetting of evidence to maximise the value of return for effort leads to attrition of cases, which impacts on success rates where success is measured as progression to the next stage. Similarly, the performance measurement of lead times does not always reflect the complexity of value-adding to the forensic evidence process by implementing changes that may extend the lead time of a stage but gain an increase in the quality of evidence, such as the introduction of an

expanded DNA marker set and probabilistic DNA interpretation software.

The repeat of the End-to-End project (E2E2) has helped consolidate learnings from the original project and measured the impact of advances in technology such as the conversion to digital imaging and the subsequent transmission of fingerprint evidence electronically, which has resulted in significant gains with respect to lead times. Other technology improvements, such as the introduction of robot ready sub-sampling and robotic analytical workflows in DNA have also had an impact, and further technology advances are expected to continue to do so. Also having an impact is a cultural shift toward greater emphasis on service delivery models and organisational reviews that incorporate LEAN thinking and focus on efficiency gains, especially in relation to fit-for-purpose integrated IT systems that support item and information management. Extended hours of coverage for crime scene investigators, at scene data entry and triage, and relocation of resources to target property crime, are a few examples of the kind of changes that have been implemented and which are improving efficiency.

The impact of E2E2 is possibly best described in terms of the response by jurisdictions to the performance measurements originally made in E2E1. Feedback from agencies indicated that many jurisdictions implemented the recommendations arising from E2E1 [44], although with varying degrees of success in terms of approaches, but with consideration of the learnings from top performers. E2E2 illustrates that there is still room for improvement. An emphasis on training for crime scene investigators with regard to the collection of value evidence and importance of collecting relevant reference samples has been shown to have a positive impact on service delivery. As jurisdictional databases grow, the identification rates for DNA profiles and fingerprints obtained at crime scenes is on the increase. Also encouragingly, since 2011, police organisations have been able to apply strategies to develop means to improve communication and outcomes at the investigation stage, allowing the benefits gained at earlier stages of the process to be realised at the arrest stage and in the overall lead times.

Declarations of interest

None.

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