STRATEGY, MARKET VISION AND INNOVATION
www.csiro.au

RESEARCH IMPACT EVALUATION

Clinical Terminology Tools

October 2017

Contents

1 Executive Summary

The challenge

Australia's health care system faces many challenges. One significant challenge is the increasing demand for clinical information to be shared between individual health practitioners, health care provider organisations, and state/territory health departments. Patient data is often captured in disparate electronic systems, different formats, and described using different clinical terminologies or 'languages'. This makes it difficult for computers to process and combine the information. The National e-Health Transition Authority (NEHTA, 2004-2016) and now the Australian Digital Health Agency (ADHA, 2016-ongoing) were established to tackle this challenge by designing the information standards for electronic health information to be shared securely. A key requirement was to develop standard clinical terminology to describe the care and treatment of patients, to allow full interoperability between electronic health systems.

The response

CSIRO research supports the goal of health data interoperability (and, more broadly the Australia's National Digital Health Strategy) by developing innovative tools and technologies for use in electronic health and medical records systems. CSIRO informatics researchers have created solutions and tools that underpin the continued development of SNOMED CT – a global clinical terminology – and its implementation for use in Australia. The tools allow improvements in the use, interoperability, and effectiveness of patient data captured in electronic medical records.

Key platform technologies include *Snorocket*, which for the first time enabled semi-real time authoring of very-large-scale clinical ontologies like SNOMED CT, and *Ontoserver*, which is a world-leading clinical terminology server implementing HL7's Fast Healthcare Interoperability Resources (FHIR) Terminology Services, and supporting syndication–based content distribution. This has led to the creation of three products, including:

- *Snapper:Map*, a web browser-based app that enables authoring maps from legacy terminology to standards-based terminologies, and *Snapper:Author*, a web browser-based app for authoring HL7 FHIR terminology resources and publishing them to a FHIR terminology server). Together, these tools support migration to and use of standard terminologies, and the adoption of the national approach to interoperable digital health information.
- *SnoMAP*, which enables diagnoses recorded using SNOMED CT-AU in an Emergency Department to be converted to ICD10-AM codes for non-admitted patient reporting purposes, thus supporting the use and re-use of the standard clinical terminology for statistical and reporting activities.
- *Shrimp*, a web browser-based app that provides an interface for searching for codes, and a dynamic and interactive hierarchy viewer. Shrimp provides exposure and learning opportunities for health informaticians worldwide.

The impacts

The developed platform technologies and products are already being adopted. The Australian National Clinical Terminology Service went live with Ontoserver in October 2016. Ontoserver is available as a free sub-licence from the Australian Digital Health Agency for use in Australia, with more than 20 licences issued so far, and four instances already in production. The Royal Australasian College of Surgeons' logbook tool uses Ontoserver to migrate from an in-house terminology to using SNOMED CT for recording surgeons' activities. SnoMAP is in regular use by the Princess Alexandra, Mackay and Townsville Hospitals, and Queensland Health more broadly, for generating ICD10-AM-based reports for ED funding purposes, as well as for improving the accuracy of clinical documentation in EDs. Shrimp is now provided as a free service; and has a growing audience of around 2,000 unique users per month around the world.

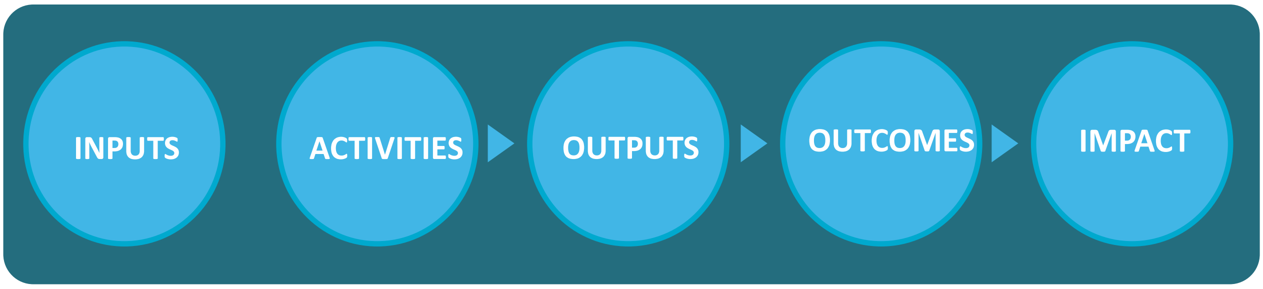
While CSIRO's Clinical Terminology Tools have been successful, there is limited information about actual gains on the health system and patient outcomes over time. Therefore, more data is needed to substantiate the impact analysis. As this was not available at the time of preparing this report, consideration of this issue is based on data published by the Deloitte Access Economics 2014 Report. The 2014 report has been subject to sensitivity analysis and/or discretion as explicitly advised in this report.

Looking at a range of impacts, our estimates suggest that CSIRO's Clinical Terminology will lead to ("CSIRO in context"):

- Total benefits (measured as reduced health systems costs and improved patient health outcomes, in real, present value terms) between $67.4 million and $269.6 million per year at maturity[1], depending on the assumptions made.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the Clinical Terminology Tools case study are summarised in Figure 1.1.

[1] Refers to the point in time, at which impacts are realised after the maximum adoption level is reached and all final users have adopted the new technology or practice.



INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACT
• CSIRO investment (FTE, in-kind contributions, equipment/facilities and background IP) • Investment from collaborators • Cost of adaptive development and extension by hospitals • SNOMED CT	• Development and validation of tools. • Stakeholder engagement for adoption (focus group, workshops etc.) • Communication (presentation, health roundtables etc.)	• Tools (Ontoserver, Shrimp, Snorocket, Snapper Platform) • Publications • Awards • Patents	***Uptake and adoption*** • Take up by Australian Digital Health Agency, the Royal Australasian Colleague of Surgeon and hospitals • Licencing fees • Improved consistency in use of standard clinical terminologies. • Informed healthcare data collection policy.	***Economic impact*** • Reduced health systems costs • Improved labour productivity. • Efficiency gains through time savings ***Social impact*** • Improved health outcomes. • Innovation (improved research and data analysis).

Figure 1.1: Impact Pathway for Clinical Terminology Tools Project

2 Purpose and audience

This case study has been undertaken to assess the economic, social, and environmental impact of CSIRO's investment in the Clinical Terminology Tools research. The case study has been prepared so it can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of CSIRO's Health and Biosecurity activities.

This case study is proposed for accountability, reporting, communication, and continual improvement purposes. Audiences for this report may include the Business Unit Review Panel, Members of Parliament, Commonwealth Departments, CSIRO, and the general public.

3 Background

Australia's health care system faces many challenges. One significant challenge is the increasing demand for clinical information to be shared between individual health practitioners, health care provider organisations, and state/territory health departments. Patient data is often captured in disparate electronic systems, different formats, and described using different clinical terminologies or "languages". This makes it difficult for computers to process and combine the information. The National e-Health Transition Authority (NEHTA, 2004-2016) and now the Australian Digital Health Agency (ADHA, 2016-ongoing) were established to tackle this challenge and design the information standards for electronic health information to be shared securely. A key requirement was to develop standard clinical terminology to describe the care and treatment of patients, to enable full interoperability between electronic health systems.

CSIRO research is supporting the goal of health data interoperability (and, more broadly Australia's National Digital Health Strategy) by developing innovative tools and technologies for use by healthcare organisations and the software industry to support the meaningful use of clinical terminology. CSIRO informatics researchers have created solutions and tools that underpin the continued development of SNOMED CT, and its implementation for use in Australia. The tools allow improvements in the use, interoperability, and effectiveness of SNOMED CT and other terminologies; and code sets for patient data captured in electronic medical records.

The clinical terminology tools were developed at the Australian e-Health Research Centre (AEHRC), a joint venture between CSIRO and the Queensland Government, in 2011. The adoption of research outputs was enabled through collaboration with external bodies, such as the Australian Digital Health Agency, SNOMED International, and Queensland Health. The AEHRC is now working with software vendors to embed the tools throughout the health system.

While much research has been done, the Health information technology (IT) industry generally struggles with implementation of SNOMED CT in their systems and there are still many open research questions which CSIRO is actively pursuing. Examples include technical research such as the expressivity of logic permitted in SNOMED CT through to the 'binding' of the terminology within information models.

4 Impact Pathway

Project Inputs

The Clinical Terminology Tools research is a collaboration between industry, government and CSIRO. Table 4.1 shows that the project has been the recipient of investment to the value of more than $8 million from 2010-11 to 2016-17. Contributors include Queensland Health, Australian Digital Health Agency, Royal Australasian College of Surgeons, Princess Alexandra Hospital, Metro South HHS, and Australian Genomics Health Alliance.

Table 4.1: Cash and in-kind support for the project between 2010-11 and 2016-17 ($ nominal)

Year	Collaborators (cash)	CSIRO (cash)	Total
2010-11 to 2016-17	$6,460,080	$1,565,270	$8,025,350

In addition, from 2007-08 to 2011-12, AEHRC has allocated three FTEstaff per annum (2 in 2007-08) to develop these tools as part of the Health Information Environment (HIE) project. This is the equivalent to an approximately $3 million investment over the five year period.

Activities

The research aims to develop tools and techniques to support the capture, use, and analysis of health data in electronic form by exploiting and extending the formal description logic foundation of SNOMED CT. The concept brief describes two phases:

- Phase 1 - Development of tools
- Phase 2 – Implementation of tools

Phase 1 - Development of tools (between 2010-11 and 2016-17)

The tools development during this period are designed to make the use of the SNOMED CT and related terminologies as simple as possible, reducing the need for a deep technical knowledge of the standards and data formats to begin capturing or working with the codes and the hierarchies.

Snapper Platform

The Snapper Platform is an application that enables the description of existing clinical terminology terms using concepts or expressions from SNOMED CT. The mapping of existing data to expressions using an ontology involves:

- Normalising the expressions, which may contain multiple codes from an ontology, for consistency purposes
- Calculating subsumption relationships, so that the relationship between expressions is understood
- Finding efficient ways to process the existing ontology extended with new terms and relationships.

Ontoserver

Ontoserver is a terminology server designed to support the requirements of SNOMED CT tooling, including the ability to manage multiple SNOMED CT extensions, subsumption queries, and SNOMED CT Reference Sets. It includes support for the Australian Medicines Terminology (AMT) and reasoning with numbers as well as LOINC, and ad hoc taxonomies.

Shrimp

Shrimp is a fast, modern browser for SNOMED CT and AMT. It requires a modern web browser (Internet Explorer 8 and earlier are not supported).

Snorocket™

Snorocket is fast and able to classify SNOMED CT at least an order of magnitude faster than other known classifiers. Snorocket was extended with new Description Logic features to support AMT and further improve performance.

Phase 2 – Implementation of tools (2014-15 - ongoing)

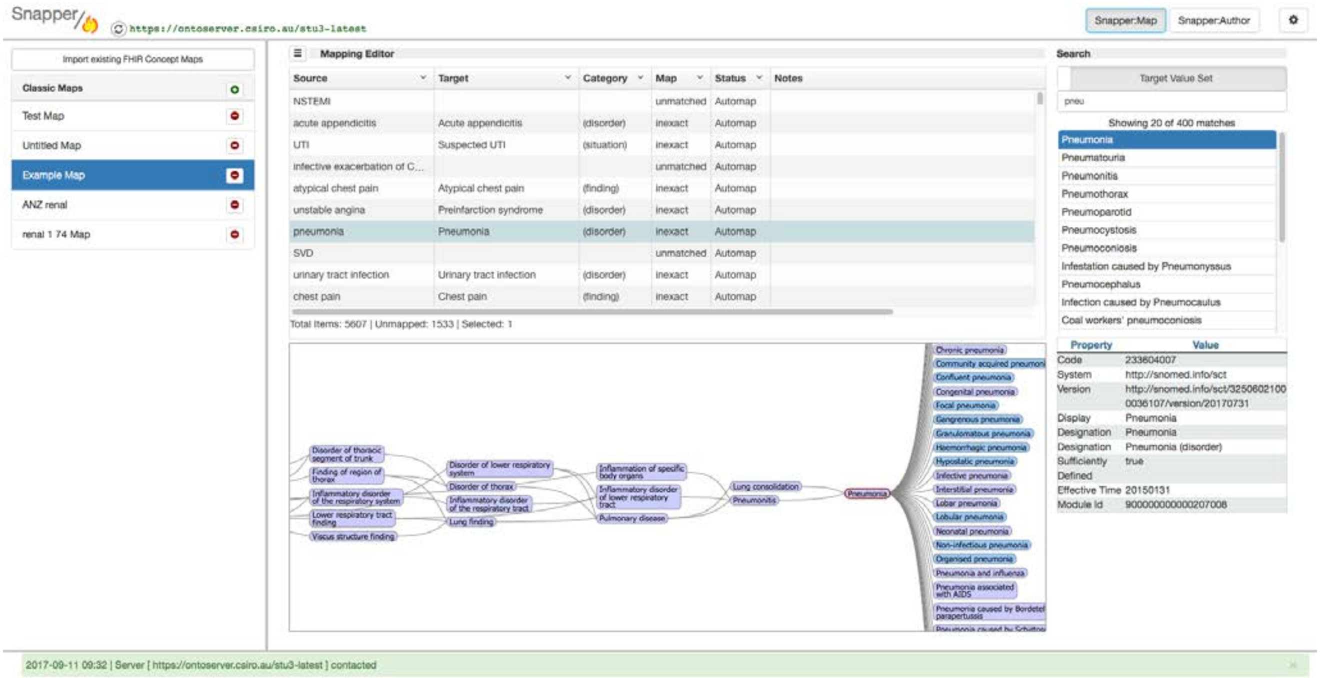
One of the most important activities subsequent to the development of the technology has been the persistent drive to ensure the adoption, as well as sustainability, of the research. There are many activities undertaken in order to articulate and refine benefits, such as focus groups and workshops with end users to determine their needs, and obtaining strategic clinician buy-in. Other activities include presenting at forums and health roundtables to promote the research outcomes; publishing technical performance regarding predictive accuracy in peer-reviewed clinical journals; filing and defending a patent on aspects of the work; and countless client and business negotiations towards improving and commercialising the technology.

The most significant activity since 2014 has been the perpetual licence of Ontoserver to NEHTA, continued by ADHA, which enabled the creation of the National Clinical Terminology Service. Ontoserver is now available for free for use in Australia. International licensing is also available – with one commercial license provided to the Best Practice Advocacy Centre New Zealand (BPAC) for their cloud electronic health record (EHR) system in the United Kingdom and other evaluation licenses for non-commercial use provided to organisations in the US, including the US Department of Veterans Affairs. Other implementation activities included supporting Queensland Health through the Princess Alexandra Hospital's Digital Hospital roll-out; and advising on the use of SNOMED CT in Cerner. This involved the development of the SnoMAP software for translating SNOMED CT to ICD10-AM for reporting and funding purposes. This software has been deployed in other hospitals across Queensland as they have adopted Cerner.

Outputs

CSIRO’s Clinical Terminology Tools enable the use of standards-based clinical terminology in digital health records to improve data interoperability, and the consistency and precision of recorded data, leading to reduced medication errors and optimised use of health data.
Key platform technologies include Snorocket, which for the first time enabled semi-real time authoring of very-large-scale clinical ontologies like SNOMED CT, and Ontoserver, which is a world-leading clinical terminology service implementing HL7’s FHIR Terminology Services and supporting syndication–based content distribution.

This has led to the creation of three products, including Snapper, SnoMAP, and Shrimp (as described above).



Source: CSIRO

Figure 4.1. An example of Snapper

Publications

1. MJ Lawley, D Truran, D Hansen, N Good, A Staib, C Sullivan. 2017. SnoMAP: Pioneering the Path for Clinical Coding to Improve Patient Care. - Studies in health technology and informatics.
2. B Koopman, G Zuccon, P Bruza, L Sitbon, MJ Lawley. 2016. Information retrieval as semantic inference: a Graph Inference model applied to medical search - Information Retrieval Journal.
3. H Leroux, A Metke, MJ Lawley. 2015. ODM on FHIR: Towards Achieving Semantic Interoperability of Clinical Study Data. SWAT4LS.
4. S Mirhosseini, G Zuccon, B Koopman, A Nguyen, MJ Lawley. 2014. Medical free-text to concept mapping as an information retrieval problem. - Australasian Document Computing Symposium.
5. A Metke-Jimenez, MJ Lawley. 2013. Snorocket 2.0: Concrete Domains and Concurrent Classification. - 2nd OWL Reasoner Evaluation Workshop.
6. B Koopman, G Zuccon, P Bruza, L Sitbon, M Lawley. 2012. An evaluation of corpus-driven measures of medical concept similarity for information retrieval. - 21st ACM international conference on Information and Knowledge Management.
7. MJ Lawley, S Colquist. 2012. Classification of pathology reports for cancer registry notifications - Health Informatics: Building a Healthcare Future.
8. S McBride, MJ Lawley, H Leroux, S Gibson. 2012. Using Australian medicines terminology (AMT) and SNOMED CT-AU to better support clinical research. – HIC.

9. B Koopman, P Bruza, L Sitbon, MJ Lawley. Towards semantic search and inference in electronic medical records: an approach using concept-based information retrieval. - The Australasian medical journal.
10. DP Hansen, ML Kemp, SR Mills, MA Mercer. 2011. Developing a national emergency department data reference set based on SNOMED CT. Medical Journal of Australia.
11. J Michel, MJ Lawley, A Chu, J Barned. 2011. Mapping the Queensland Health iPharmacy Medication File to the Australian Medicines Terminology Using Snapper. - Studies in health technology and informatics.
12. DP Hansen, M Giermanski, M Dujmovic, J Passenger. 2011. Building SNOMED CT Reference sets for use as interface terminologies. Electronic Journal of Health Informatics.

IPs/Patents

The table below provides details of the title, registration number and status of the active Australian filed patents arising from the project.

Table 4.2: Title, registration number and status of the active Australian filed patents

Title	Registration number	Status
"Mechanism for guided composition of a description logic expression"	WO2011160171	Granted

Source: CSIRO.

Awards

- iAwards:
  - 2017 AIIA Pitchfest winner (Public Sector & Government) for NCTS
  - 2017 Qld winner for NCTS in two categories
  - 2016 National Merit for SnoMAP
  - 2012 Qld Winner for Terminology Tooling
  - 2010 Qld Merit for Snapper
- Branko Cesnik Best Scientific Paper nomination, HIC 2017.
- Branko Cesnik Best Scientific Paper, HIC 2011.
- Payne-Scott Best Paper Award, AOW 2010, "Fast classification in Protégé: Snorocket as an OWL 2 EL reasoner.

Outcomes

The combination of tools and technologies developed by CSIRO are considered to enable faster development and uptake of SNOMED CT-AU (which is the Australian extension to SNOMED CT, providing local variations and customisations of terms relevant to the Australian healthcare community) in the Australian health system; and, as a result, improve the use, interoperability and effectiveness of data captured about a patient. This in turn has led to improved service efficiency, improved patient outcomes, improved societal outcomes, and, potentially, improved research outcomes.

Both the platform technologies and products are already being adopted. The Australian National Clinical Terminology Service went live with Ontoserver in October 2016; and made it available as a free sub-licence from the Australian Digital Health Agency for use in Australia. The Royal Australasian College of Surgeons' logbook tool is using Ontoserver to migrate from an in-house terminology to using SNOMED CT for recording surgeons' activities. SnoMAP is in regular use by the Princess Alexandra Hospital, Mackay and Townsville Hospitals, as well as Queensland Health more broadly, for generating ICD10-AM-based reports for ED funding purposes, as well as improving accuracy of clinical documentation in EDs. Shrimp is now provided as a free service; and has a growing audience of around 2,000 users per month around the world.

Although the target for adoption of CSIRO's clinical terminology tools is hospitals and health departments, GP clinics could also potentially benefit from the interoperability enabled by these clinical terminology tools. According to Bartlett et al. (2010), there are a total of 7,261 GP clinics in Australia which have standalone Electronic Medical Records systems currently without connectivity to other electronic health records systems (e.g. hospital electronic health records).

Current work underway combines the use of Ontoserver and Snapper (for authoring of maps between GP systems code-sets and SNOMED CT) coupled with FHIR resources to incrementally improve the quality of patient data being retrieved from GP systems for public and population health purposes. To date, the data collected in GP systems is non-standard and non-comparable. This means a comprehensive overview of primary health care is not possible.

Impacts

The Clinical Terminology Tools are targeted at improving health information management which leads to a variety of impacts, most significantly reduced health system costs, improved health outcomes, and time savings. The following impacts of clinical terminology tools were identified:

Table 4.3: Summary of Clinical Terminology Tools impacts

TYPE	CATEGORY	INDICATOR	DESCRIPTION
Economic	Productivity and Efficiency	Reduced health system costs	The use of clinical terminology tools and shared information, as part of an e-Health platform more broadly, has resulted in reduced health system costs and improved service efficiency. This is achieved through a better identification of most effective treatment and by reducing the use of services that are not needed
	Productivity and Efficiency	Time savings at data entry	This impact refers to a reduction in the time spent entering data and generating information. Information is immediately

			available, can be referenced, and the need to duplicate information capture further down the line (e.g. through coders in a hospital) is removed.
	Productivity and Efficiency	Increase in labour productivity and labour force participation	A more targeted treatment and reduction in the number of adverse drug events due to information errors will lead to an increase in labour productivity and labour force participation. This impact encompasses illness-related lost earnings, absenteeism, premature death and additional search and hiring costs for replacement workers
Social	Health and Wellbeing	Improved patient health outcomes	The use of clinical terminology tools within an e-Health platform results in a reduction of human error and, thus, leads to fewer adverse events and improved patient safety. In other words, these tools enable a more targeted treatment, leading to healthier outcomes
	Innovation	Improved research and data analysis	The use of clinical terminology tools has will provided a larger pool of consistent medical data accessible by researchers compiling information. Therefore, a shared platform along with the clinical terminology tools can not only reduce researchers' time effort on data gathering for both clinic patient management and more holistic research assessment purposes, but also result in better research analysis from the improved information

5 Clarifying the Impacts

Counterfactual

The Australian Digital Health Agency is responsible for setting the Australian standards to enable the development of an electronic enabled health system. A key component of this is a single clinical terminology to enable interoperability between electronic health systems. In order to achieve this NEHTA (now ADHA) committed to providing an Australian version of SNOMED CT, SNOMED CT-AU, and an Australian Medicines Terminology (AMT).

In the absence of the outputs and outcomes delivered by CSIRO, NEHTA (ADHA), vendors and health departments would have needed to source comparable services from other organisations, which are currently not of the same level of functionality that CSIRO is able to provide. Alternatively, vendors or health departments would have needed to develop their own solutions, resulting in delays in the development of AMT and SNOMED CT derivatives. CSIRO estimates that the overall impact of the absence of these outputs and outcomes will lead to a delay in the successful development and deployment of SNOMED CT-AU and the AMT by at least two years. Interoperability can only be attained through the adoption of standard terminologies and health data collection processes. CSIRO tool suites are standards compliant and enable all e-health participants to meet national protocols and requirements in health data management. Without such tools, there would be a risk that different and various other tools developed by a range of stakeholders would disperse and dilute the drive to national standardisation of health information.

Attribution

100 per cent of the research effort required to deliver the outputs detailed in this case study was led and undertaken by CSIRO. However, the impact calculation is based on benefits from the successful implementation of the broad areas of Electronic Medical Records, Medication Management, and Decision Support. CSIRO estimated that its attribution for the research outputs required to enable the impacts is 25 per cent. This figure is a modest estimate, as there are other research and development outputs required to enable the assessed impacts which have not been considered in this study. As the impacts mature over time, it is recommended that this figure be reassessed in the future.

It is important to note that the adoption of research outputs has been enabled through the collaboration with external bodies, such as NEHTA, the International Health Terminology Standards Development Organisation (IHTSDO), and Queensland Health. Multiple stakeholders are needed for the wider adoption of these clinical terminology tools, particularly as Ontoserver and Snorocket need to be embedded in other tools.

It is likely that other inputs (such as implementation of the new systems, training, or new equipment) are required to unlock the full impacts. However, insufficient information was available to refine the attribution estimate, which remains largely assumptions based.

6 Evaluating the Impacts

Cost Benefit Analysis

Modelling approach

This section examines the impacts that CSIRO's Clinical Terminology Tools have generated (economic, social, and environmental). This analysis examines two types of impacts, namely economic and non-economic impacts. Economic impacts are considered to be impacts that have a definitive dollar value, such as an increase in productivity, or a reduction in costs expended to Australian health system. Non-economic impacts are those qualitative impacts, such as improved health outcomes.

We calculated the research outcome deployment and counterfactual scenarios to determine the value of the entire research program benefits (where quantification was possible). The counterfactual scenario represents the pathway where CSIRO's Clinical Terminology Tools research outputs are not implemented, and a 'status quo' or extension of current trends prevails. The benefits calculated in the analysis are the net benefits from the program, that is, the difference between the 'with' and 'without program' scenarios. The analysis is equivalent to carrying out separate analyses for the 'with program' and 'without program' scenarios and calculating the difference between them.

Due to data constraints, many of the assumptions required to value the impacts are uncertain. While reasonable and conservative assumptions have been made in the analyses, the results should be viewed with some caution. This valuation provides a ball-park estimate of the potential net benefits, therefore requires the need for a follow-up revision of the valuation once the results of the accurate uptake/adoption become available.

Table 6.1: Value of the Clinical Terminology Tools (CTT) project

	Efficiency in health service provision	Patient health outcomes
- With program (CTT project case A)	Various	Various
- Without program (base case B)	Various	Various
- Savings (C= B-A)		

Refresh of the Cost Benefit Analysis results from 2014

We have 'refreshed' the economic analysis component of CSIRO's Clinical Terminology Tools research undertaken in 2014 by Deloitte Access Economics (DAE) to bring the costs and benefits calculated up to date.

Costs and benefits have been recalculated in order for them to be expressed in a dollar value at a common point in time, namely in 2016-17 dollars, using the Consumer Price Index. Present value[2] calculations of costs and benefits have also been harmonised so that they have a common base year (2016-17) across the projects. A real discount rate of 7 per cent has been assumed in these present value recalculations. It is important to emphasise that we have not sought to review the assumptions underpinning the 2014 report.

Benefits considered include the increased economic activity in Australia generated by the implementation of research findings, namely reduced health system costs, improved health outcomes, and licensing revenue, as well as the valuation of any social benefits that flow from the research undertaken by CSIRO and its collaborators.

Reduced health system costs

CSIRO's clinical terminology tools have been adopted relatively early in the health sector as a direct consequence of NEHTA engaging with CSIRO (using the Clinical Terminology Toolkit) to successfully develop SNOMED CT-AU and the AMT. These are key components of NEHTA's e-health strategy. This is significant as a previous attempt by NEHTA to develop the AMT without engaging CSIRO had been unsuccessful. Based on this reasoning, a reasonable assumption is that the benefits associated with the implementation of NEHTA's e-health strategy will be realised two years earlier.

Assuming interoperability of electronic health data will provide benefits for Electronic Medical Records, medication management and decision support of $4.8 billion per annum at maturity (leading to improved service efficiency), and assuming that the clinical terminology tools developed and services delivered by CSIRO (along with the other research outputs attributed with the remaining 75 per cent of the enabled impact) bring forward interoperability in the Australian Health System by two years, the value of reduced health system costs is $612.6 million per annum at maturity. Maturity for this impact is expected by 2020. The calculation for this impact is presented in Table 6.2.

[2] One key metric of a cost-benefit analysis is the Present Value (PV) of costs and benefits. Net Present Value (NPV) is the difference between the present value of benefits and the present value of costs over the chosen analysis period (which varies between projects) under the chosen discount rate (in this case 7 per cent). The discount rate is applied to reflect the fact that the value of a dollar in the future is less than it is now.

Table 6.2: Impact calculation of health system costs

	Measure	Value	Sources
	With CSIRO research		
A_R	HIE relevant e-health benefits: Electronic Medical Records, Medication Management, Decision Support [$ per annum]	$4,861.5m	Bartlett et al. (2010)
B_R	Direct costs by GP practices to establish and maintain connectivity [$ per annum]	$20.9m	DAE estimate based on Bartlett et al. (2010)
C_R	Net benefits to the health system [$ per annum]	$= A_R - B_R$ = $4,840.6m	
	Counterfactual		
C_c	Net benefits to the health system realised two years later [$ per annum]	$= C_R/(1+7\%)^2$ = $4,228.0m	
	Impact: world with CSIRO research – counterfactual		
	Net benefits from accessing to health system cost benefits two years earlier [$ per annum]	$= C_c - C_R$ = $612.6m	

Note: Monetary values are presented in 2016/17 $AUD.

Improved health outcomes

A reduction in human error, fewer adverse effects, and improved patient safety are the main health impacts from the use of clinical terminology tools, which can reduce the cost of lifetime lost every year due to a variety of illnesses caused by adverse effects of medical treatment by approximately 56 per cent. The value associated with the improved health outcomes as a result of clinical terminology tools is $61.3 million per annum at maturity. According to Bartlett et al. (2010), 10.4 per cent patients are affected by adverse drug events or errors, which include having the wrong dose or medications prescribed. The calculation for this impact is presented in Table 6.3.

Table 6.3: Impact calculation of improved health outcomes

	Measure	Value	Sources
	With CSIRO research		
A_R	Adverse effects of medical treatment (DALY per 1000 people)	0.2	AIHW (2003)
B_R	Australian population ('000)	24,590.79	ABS (2016)
C_R	Share of hospitals or GP clinics in Australia having stand-alone Electronic Medical Records systems without interoperability [%]	95%	Bartlett et al. (2010)
D_R	Adverse effects attributed to HIE	56%	DAE estimate based on Reckmann et al. (2009)
E_R	Number of cases avoided of adverse effects of medical treatment per annum	$=A_R*B_R*C_R*D_R$ =3,270.6	
F_R	VSLY ($)	$185,073	OBPR (2008)

G_R	Value of life associated with cases of adverse effects avoided [$ per annum]	$= E_R * F_R$ = $484.2m	
	Counterfactual		
G_c	Value of life lost per year associated with cases of adverse effects avoided (E_R realised two years later) [$ per annum]	$= G_R / (1+7\%)$ $423.0m	2
	Impact: world with CSIRO research – counterfactual		
	Value of life associated with cases of adverse effects avoided [$ per annum]	$= G_c - G_R$ = $61.3m	

Note: Monetary values are presented in 2016-17 $AUD.

Licensing fees and additional services provided by CSIRO

To date, the research has resulted in licensing of the software by the Australian Digital Health Agency, SNOMED International, and Queensland Health. Currently, CSIRO receives 100 per cent of licence fees for Snapper and Ontoserver. CSIRO has a commercialisation strategy that aims at doubling technology uptake by large high-value enterprise and government customers.
Over the past three years, licensing of the tools and consulting services to support implementations have returned significant revenue to CSIRO; and these revenues are forecast to grow over the next few years. Licensing revenue is estimated to be $1.5 million between 2010-11 and 2016-17. The licensing has also generated international consulting services for CSIRO.

The perpetual licence of Ontoserver to the ADHA that enabled the creation of the National Clinical Terminology Service (https://www.healthterminologies.gov.au/). Ontoserver is now available for free for use in Australia. CSIRO has also given a licence to BPAC (NZ) for their cloud EHR system in the UK.

Further impacts

This section provides an overview of the causal linkage from the adoption of the clinical terminology tools to generate other impacts that could not be quantified, along with examples evidencing the extent to which they have been realised to date.

Time savings at data entry

The use of clinical terminology tools provides a time benefit by speeding up the information generation process. Data can be entered directly into the system, which means that information is available in real time. In hospitals, this reduces the need burden on coders, who are currently required for data entry and interpretation from clinical notes.

This impact could be quantified as the reduction in the number of FTE and labour cost associated with data coding, which can be avoided or redeployed in other activities. However, there is no detailed information or measurement in the trials to date that demonstrates the order of magnitude for this impact.

Time savings for (secondary) use of data

The use of clinical terminology tools also reduces the time spent searching for and interpreting patient data. Using consistent clinical terminology reduces the effort associated with transforming health data manually at points of data exchange. Points of data exchange may include clinical purposes, such as decision support and sharing information between clinicians, as well as secondary purposes, such as financial reporting (coding), screening, disease surveillance, and knowledge management.

This impact could be quantified as the reduction in the number of FTE and labour cost associated with secondary use of data. Impacts are likely to extend to all types of health providers (to the extent that they have adopted clinical terminology tools); however, there is no detailed information or measurement in the trials to date that demonstrates the order of magnitude for this impact.

Improved research and data analysis

Having a shared platform to access medical data with consistent classification is likely to improve the aggregation of information and basis for research and data analysis, mainly by accessing larger samples of medical data. This impact can be realised through health departments, hospitals, or medical colleges, which can benefit from data repurposing for other applications, such as population health/epidemiology, policy, strategy, research, and education.

This impact can be assessed through the value of savings in labour time required towards data collection and management to integrate different datasets, while demonstrating key outcomes of the data use and analysis undertaken (e.g. through a number of studies or publications). Given the early stage of adoption, it is unlikely that this impact has been realised yet. Any improved research and data analysis undertaken directly by CSIRO would need to be treated as a feedback loop rather than a separate impact.

Increased labour productivity and labour force participation

Adverse health impacts not only generate direct financial costs to the health system and non-financial costs of the burden of disease, but a range of additional costs to the Australian economy. Some of the additional flow-on impacts are described by Access Economics (2006) as follows:

- Productivity losses – short and long-term employment impacts and premature mortality;
- Carer costs – the value of community care services provided primarily by informal carers;
- Deadweight Loss (DWL) from transfers – taxation revenue foregone, welfare and other government payments; and,
- Other costs – aids, equipment and modifications, transport and accommodation costs, respite and other government programs and the bring-forward component of funerals.

In this case study, increased labour productivity and labour force participation are flow-on effects from having more targeted patient treatments and reducing the number of ADE occurrences associated with errors from information management systems. A healthier workforce is generally more productive and spends less time out of work due to ADE related treatments and complications.

Distribution effects on users

The main beneficiaries from time savings in data input and search are direct users, such as hospitals and health service providers.

The main beneficiaries of reduced health system costs are taxpayers. Patients are the beneficiaries of improved health outcomes (more targeted treatment, leading to healthier outcomes). Specifically, patients with long-term care needs and chronic conditions are likely to benefit through their health data and longitudinal records being available to multiple care providers. Patients with complex conditions are also likely to benefit from new kinds of research and comparative analysis into treatment paths.

Externalities or other flow-on effects on non-users

Compared with the counterfactual, CSIRO's clinical terminology tools bring forward the implementation of clinical terminology in Australia by two years. As such, alternative health data integration tools and CSIRO's clinical terminology tools are likely to be operated similarly and require common inputs. To the extent that, aside from timing, clinical terminology tools developed by CSIRO are comparable to alternative systems, externalities, and other flow-on effects are considered negligible in the context of this analysis.

In reality, however, those impacts may not be zero. There may be some flow-on effects and externalities associated with bringing forward the implementation of clinical terminology in Australia by two years. There may also be externalities and flow-on impacts associated with the fact that the technology developed by CSIRO is superior to alternative systems. However, insufficient information was available to explore those impacts in more detail.

Aggregation of impacts and attribution to CSIRO research

The benefits described here are additive. Assuming that CSIRO attribution is 25 per cent, the impacts generated by clinical terminology tools that are attributable to CSIRO research are valued at $168.5 million per annum at maturity, as shown in Table 6.4.

Table 6.4: Summary of impacts from Clinical Terminology Tools at full maturity ($ per annum)

	Impact	Quantified in monetary terms?	Type	Annual value
i	Reduced health system costs	yes	Economic	$612.6m
ii	Improved health outcomes	yes	Social	$61.3m
iii	Time savings at data entry	no	Economic	-
iv	Time savings for (secondary) use of data	no	Economic	-
V	Improved research and data analysis	no	Economic	-
vi	Increased labour productivity and labour force participation	no	Economic/Social	-
	TOTAL			**$673.9m**
	TOTAL ATTRIBUTABLE TO CSIRO (25%)			**$168.5m**

Note: Monetary values are presented in 2016-17 $AUD.

7 Sensitivity analysis

Estimates are surrounded by a significant degree of uncertainty. Some of the most significant risks and issues affecting the impact estimates include variations to the assumptions around:

- E-health benefits due to EMRs, Medication Management and Decision Support (the current estimate relies on a single report from 2010 with results based on in-house modelling rather than empirical evidence);
- Adverse effects attributed to HIE (the current estimate is based on trials undertaken overseas);
- Benefits being brought forward by two years (the current estimate is based on CSIRO assumptions); and
- Attribution (while the current estimate takes into account other inputs, it remains largely assumptions based).

Given these uncertainties, it would be useful to look at results under different discount, adoption, and attribution rates. The results of that analysis are shown in Table 7.1. While the parameters used in the base-case scenario seemed reasonable in the light of current realities on the ground, it is nevertheless important to test the robustness of our conclusions to variations in these assumptions. Based on the sensitivity analysis, we estimate that the PV benefits of the Clinical Terminology Tools research is between $67.4 million and $269.6 million per year.

7.1: Results of sensitivity analysis

Assumption	Low assumption	Central assumption	High assumption	PV benefits ($m) (low)	PV benefits ($m) (central)	PV benefits ($m) (high)
Discount rate (%)	5	7	10	123.8	168.5	231.0
Adverse effects attributed to HIE (%)	30	56	70	161.4	168.5	172.3
E-health benefits ($m)	3,862	4,862	5,862	136.8	168.5	200.1
CSIRO contribution (%)	10%	25%	40%	67.4	168.5	269.6

Note: 1) PV is present value and 2) Monetary values are presented in 2016-17 $AUD.

8 Limitations and Future Directions

This evaluation uses a mixed methodology to evaluate the research impact arising from CSIRO's Clinical Terminology Tools. It combines quantitative and qualitative methods to illustrate the nature of the technology's economic, environmental, and social impacts. In cases where the impacts can be assessed in monetary terms, a cost-benefit analysis (CBA) is used as a primary tool for evaluation. As a methodology for impact assessment, CBA relies on the use of assumptions and judgments made by the authors. This relates primarily to the economic indicators for impact contribution, attribution, and the counterfactual. These limitations should be considered when interpreting the results presented in this case study.

Given the scope and budget for the analysis, we acknowledge that there are some limitations with regard to the evidence base of impacts. For our analysis, we have relied on the 2014 study and other analyses conducted across Australia and internationally. As such, our analysis is limited by the constraints within these studies. For instance, due to data limitations, the actual effectiveness of the tools post-implementations across the country was based on estimates only as limited information was available about the actual gains over time. Results from the 2014 report have been subject to sensitivity analysis and/or discretion as explicitly advised in this report. In addition, social benefits were not quantified, but were treated as potential impacts, owing to a lack of reliable data.

9 References

AIHW, Begg S, Vos T, Barker B, Stevenson C, Stanley L & Lopez A 2007. The burden of disease and injury in Australia 2003. Cat. no. PHE 82. Canberra: AIHW. Viewed 18 July 2017. <http://www.aihw.gov.au/publication-detail/?id=6442467990>.

Australian Bureau of Statistics (ABS), 2016. Cat 1301.0 Year Book Australia. Population – Households and Families. ABS, Canberra.

Bartlett, C, Boehncke, K, Johnstone-Burt, A, and Wallace, V, 2010. Optimising E-Health Value Using an Investment Model to Build a Foundation for Program Success. Booz&Co report. Available in http://www.booz.com/global/home/what-we-think/reports-white-papers/article-display/optimizing-health-value-using-investment?gko=fb031

Reckmann MH, Westbrook JI, Koh Y, Lo C, Day RO, 2009. Does computerized provider order entry reduce prescribing errors for hospital inpatients? A systematic review. Journal of the American Medical Informatics Association. 16, pp. 613–623.

Office of Best Practice Regulation (OBPR), 2008. Best Practice Regulation Guidance Note – Value of statistical life.

Deloitte Access Economics (2014). Evaluation of CSIRO’s research impacts – Impact Case Studies. CSIRO, Canberra.

CONTACT US

t 1300 363 400

+61 3 9545 2176

e enquiries@csiro.au

w www.csiro.au

AT CSIRO WE SHAPE THE FUTURE

We do this by using science to solve real issues. Our research makes a difference to industry, people and the planet.

As Australia's national science agency we've been pushing the edge of what's possible for over 85 years. Today we have more than 5,000 talented people working out of 50-plus centres in Australia and internationally. Our people work closely with industry and communities to leave a lasting legacy. Collectively, our innovation and excellence places us in the top ten applied research agencies in the world.

WE ASK, WE SEEK AND WE SOLVE

FOR FURTHER INFORMATION

Strategy, Market Vision and Innovation

Dr Anne-Maree Dowd

Executive Manager

t +61 7 3327 4468

e anne-maree.dowd@csiro.au

w http://my.csiro.au/impact