The HWMD maturity model: A foundational framework to measure effectiveness of institutional research e-infrastructures

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There is a nationally recognised need for a framework and tools to measure progress in implementing e-infrastructures for research from an institutional, organisational unit and service perspective. This paper describes the development of a prototype maturity model and self-assessment tool in response to that need. The authors present a background to the environment of technology enabling services for research and the challenges of fluidity of boundaries around traditional services and roles as institutions respond to the needs of the research community. The conceptual basis of the model is presented along with the model and its various elements that explain how the model is in its current form. The information provided in this paper, combined with field site test feedback, will promote discussion and debate amongst the community and opportunities will present to gather input to optimise the model. The next steps would be to further elaborate and test the constructs and indicators of the model in field test sites and to further develop the self -assessment tool.

Introduction

Australia is recognised globally for high quality research. In 2013 Australia ranked 9th in the OECD for research outputs in terms of publications and increased its relative citation impact by 76% over 9 years to 2013. However, over the same period Australia's innovation performance has declined and our global competitiveness has gone from fifth in the world to eighteenth according to the World Economic Forum (Department of Education & Department of Industry, 2013). New knowledge created in universities and public research organisations drives innovation in the private sector and federal government investment in the research workforce, research infrastructure and projects requires a demonstrable return on investment.

At the same time, institutions are focused on optimising research performance, management and administration processes to: enable national and international benchmarking by the Australian Research Council (ARC) through *Excellence in Research for Australia* (ERA); to build research capacity; and to promote Australia's research strengths on the world stage (ARC, 2015). Additionally increasing attention is shifting towards an institution's data assets and how to capitalise on quality data outputs, data sharing and the re-use of datasets to enable faster knowledge discovery and increased innovation (Research Data Infrastructure Committee (RIDC), 2014). Good performance in this area increases an institution's national and international standing (Bischel, 2012).

Significant national government investment such as the Education Investment Fund (EIF) and the National Collaborative Research Infrastructure Strategy (NCRIS) has supported the development of research computing resources: the Australian Research Cloud; discipline based virtual labs; large scale data storage; and has increased capacity to support research data management services to a level that most Australian institutions now have capacity to offer data sharing services. These resources have the potential to give researchers a competitive advantage in obtaining research funding and to attract international interest in partnering with Australian researchers (RIDC, 2014; Bischel, 2012).

Researchers and institutions have responded in different ways to these new enabling technological capabilities collectively termed 'e-Research'. How researchers or research groups engage with e-Research is dependent upon the sort of research they are involved in. For example: genomics researchers will be interested in having large compute capacity available on demand; an international collaborative educational research project will be interested in collaboration tools and file sharing; and another researcher will be looking for a specialist research data management service. There are the high performance technology users (such as genomics researchers) and at the other end of the scale, there is what is referred to as the long-tail of researchers. These are the individuals or small groups of researchers

not using high performance infrastructure but they nevertheless need access to collaboration tools, data storage services and research data management specialist input. For those delivering e-Research services within institutions the scope and boundaries are traditionally defined by the discipline of that service for example; information technology (IT) services, Library and information services. Those boundaries are becoming more fluid and often unclear as institutions respond to the needs of the research community.

As the necessary workforce capabilities have evolved in different organisational units from Library and Information services, IT and computing services, research offices and more recently e-Research units and e-Research organisations, researchers, as well as those delivering technology enabling services, define e-Research differently thereby causing confusion amongst stakeholders, not least researchers and those attempting to deliver services. This lack of clarity also extends to policy and governments with differences often reflecting the perspective and agenda of the authors of the definition. International perspectives also differ with the U.S. referring to cyber-infrastructure and research computing; and in the UK eScience, e-Research and e-infrastructure. Appendix 1 lists some of the current definitions found in the literature in common use describing the domain of technology enabled research.

There is a nationally recognised need for a framework and tools to measure progress in implementing e-infrastructure for research from an institutional, organisational unit and service perspective. This paper describes the development of a prototype maturity model and self-assessment tool in response to that need. Further work is ongoing and field testing and validation is required as next stages.

Stakeholder engagement

There have been some attempts at sector wide coordination through initiatives such as: AeRO (Australian e-Research Organisations) IT Research Support Expert Group; and the CAUDIT (Council of Australian Universities Directors of Information Technology) Research Working Party; to leverage and promote the use of federal government funded e-Research technological infrastructure into the institutional environment.

At the same time library and IT organisations within universities have been challenged with ways to create and improve research services and have been looking for ways to seamlessly connect researchers to these services, whether developed in-house or as part of a research community. CAUDIT and CAUL (Council of Australian University Librarians) have a formalised partnership and both acknowledge that researchers and institutions do not necessarily separate the e-Research infrastructural components into discrete facilities but rather engage with them along the research pathway. They agree that there is a need to try and integrate the e-Research environment however, due to the evolutionary nature and role of these facilities, they require separate governance and engagement models to be successful (CAUDIT 2011, CAUL 2011). There is no clear picture of how CAUDIT and CAUL members are engaging with their research communities, the level of integration in e-Research service delivery within and between institutions, and how effective are the different approaches to service delivery. Given this context, it is hardly surprising that many senior managers find it difficult to measure performance in meeting the needs of researchers.

The reality is that all research requires the use of information and communication technologies and tools - from the simple to the highly complex, powerful and specialised. Provision of information, data and technology services for researchers continues to evolve in Australian institutions and in other countries in response to the demands of researchers, departments and faculties and the opportunities presented by new technology and infrastructure capabilities. The diversity of these demands has often meant that the knowledge, skills and tools within existing organisational units have been leveraged to make the best use of the emerging technological solutions in support of the researcher (Dahlstrom, 2014). One size does not fit all as eResearch/e-Research Infrastructure/Research computing support services are delivered differently in institutions, often in siloed disparate ways within individual institutions. Many services are converging over time in response to local need. One example of this is where IT support staff are co-located in academic libraries and the library-IT inter-professional team offer a seamless service to researchers.

International experience

Internationally, organisations such as: EDUCAUSE- a U.S. not for profit association of IT leaders and professionals committed to advancing higher education; and JISC (formerly the Joint Information Systems Committee)– a U.K. not for profit charity with members from higher and further education institutions who champion the use of digital technologies in UK education and research; have been addressing similar issues.

JISC (http://www.jisc.ac.uk/) offers subscription membership only to UK education learning and research providers. It provides access to national digital content, national network and IT services and open access to best practice guides and toolkits designed to help researchers and academics get the best from digital technologies in education and research (e.g. a guide to measure the impact of your digital resources).

EDUCAUSE offers subscription membership to U.S universities, colleges, not for profit organisations and corporations serving the higher education IT market. International subscription is available to universities recognised by the International Association of Universities (IAU). EDUCAUSE also provides open access to publications, research findings, thought leadership and performance measurement surveys. A number of these guides and toolkits are named and referenced later in this paper.

International research focus has turned to the challenges surrounding the uptake of e-Research and e-infrastructure following investment and attempts to understand the challenges and to address barriers that may prevent sustainable use of the available enabling technologies (Voss et al, 2007; Lynch 2008).

Australian universities and research institutions must innovate to compete in the global knowledge economy and also collaborate to compete within Australia for funding to build the fundamental research information infrastructure. At the same time they must demonstrate effective stewardship and informed investment decisions to deliver success in the short and medium term underpinned by a strategy of sustainability (O'Brien 2010).

Development of an e-infrastructure for research maturity model for higher education institutions

Many questions remain unanswered around how to measure progress in services implementing e-infrastructure capabilities and capacity. As discussed in the previous section, e-Research enabling services are by nature heterogeneous given the enormous variation of service profiles that exist and the university specific factors that influence a university response to the issues. Therefore, existing service performance measures and indexes from for example, JISC or EDUCAUSE may not be meaningful without considerable modification.

The annual eResearch Australasia conference held in Melbourne in late October 2014 provided a valuable opportunity to engage with a wide range of stakeholders: system owners of funded eResearch tools and applications; jurisdictional eResearch service providers; and institutional support staff. The authors facilitated a well-attended 'Birds of a Feather' (BOF) focus group session to gather opinion and views to inform the development of a framework for institutions to measure progress. Questions posed to the group focused on: measuring performance of eResearch enabling services; metrics; best practice within institutions; effectiveness; and ideas about what maturity looks like.

The facilitators presented a preliminary tentative maturity model to the group to test the concept and its acceptability. The general consensus was that a maturity model would be more valuable at this point in time. Although this approach is extremely challenging given the high degree of variation in services, the group identified that the maturity model would have utility as:

- A benchmarking tool
- A model that can be used within an institution to help focus on the development of integrated library, IT services and infrastructure to support research and
- A reference point to frame further discussion about supporting researchers across the sector.

As a further step in the development of a suitable maturity model and in response to this changing environment a brief review of the literature was undertaken. As a consequence the issues were reframed to place the components of e-Research in a socio-technical ecosystem view. This view reflects how researchers work as well as incorporating the value of research outputs and research data as assets. An underlying theme of this approach was to identify where service delivery can add value to the research activity.

The majority of measurement tools, matrices, indexes and tools reviewed were designed and developed for specific single function services e.g. IT, Research Data Management, Library, Information services. However, there was significant overlap in what these tools identified as activities and expertise within their realm of responsibility and in the case of practitioners, their scope of practice. Content analysis of some Australian university, UK and US websites also identified considerable overlap in description of services offered to the research community irrespective of the label attached to the service.

Socio-technical ecosystem conceptual view

The authors propose a socio-technical view of eResearch service delivery (Figure 1). One that is service delivery focused, organisational unit and institution agnostic and attempts to remove the complex arrangements around delineation of boundaries, overlap and duplication of the various providers of e-Research services to researchers. This view is foundational to the development of a sustainable maturity model that focuses on the researcher and their needs at the centre of the specification, design, development and delivery of effective e-Research services.

Figure 1. The socio-technical view of eResearch service delivery context

Implementation of e-Research capabilities, Creating, managing curating and sharing research data involves a wide range of e-Research capabilities, whether technological, information and data related, or requiring workforce skills is complex and difficult. Borgman (2012) refers to this situation as the research conundrum. The approach taken to try to tease apart the puzzle is supported by a key emergent theme of a 3 year research project, reported in the book *Legal Framework for e-Research: realising the potential*.

> "Ultimately research is originated by people and in building the e-Research platform we are embedded in a network of human as well as technological relationships. We need to understand how these relationships exist and how they may be nurtured and accommodated or might even change in this new landscape." (Fitzgerald, 2008; p. 2).

Edwards (2009) and Ribes (2010) also highlight the social aspect. They noted the complexity of providing technology enabled research services and suggest that a focus on e-infrastructures will help provide an understanding of how institutions can grow a stable infrastructure: social and technical; in response to a changing environment.

Dimensions of the maturity model

The Holewa, Wolski, McAvaney & Dallest (HWMD) maturity model proposed below has been developed by the authors based upon existing knowledge both within Australia (disciplinary subject matter expertise, AeRO IT research support expert group, CAUDIT Research support working group, CAUL, ANDS projects) and internationally (EDUCAUSE, JISC, and the Research Data Alliance) as well as the authors' experiences within their institutional settings. The maturity model is intended to help e-Research service providers to understand where they are currently, their readiness to provide new services and what functions they need to prioritise to improve their effectiveness. It could also be used to flag to senior executives a) dependencies on organisation wide concerns e.g. collaboration and communication b) gaps in provision, c) overlap and potential duplication and) workforce capability and capacity. It can be used to inform strategy development, business case preparation and justification for additional allocation of resources.

The authors have focused on a) what services the researcher/research group requires to undertake research in a highly productive technology enabled way leveraging available data/information; and b) what core integral service functions are also required to enable the researcher/research group to improve performance. The authors propose six dimensions that are relative to effective eResearch delivery: a) governance and leadership, b) research information and data management, c) technological infrastructure, d) collaboration and community engagement, e) workforce education, training and development and, f) service delivery and management, as shown in Figure 2 below.

Figure 2. Six Dimensions of eResearch Enabling Functions

These six dimensions contain sub-components relevant to measuring eResearch specific service effectiveness. The sub-components have a number of indicators that are used to measure the effectiveness of eResearch service maturity across an institution and in discrete organisational units or services. Table 2 at the end of this section gives examples of subcomponent indicators. The model is designed to work across varying levels of organisational complexity by being service, institutional or organisation agnostic. Persons wishing to gauge their effectiveness can focus on their entire institution (such as University wide approach), an organisational unit, or service.

The following discussion elaborates on the sub-components within each dimension. The sub-components have been developed from knowledge gained from the literature as well as from the author's experiences working within institutional contexts.

Governance and leadership

This dimension is concerned with the executive and overarching ownership of e-Research in the institution including planning and budget response, policy development and implementation, organisational structures and processes (Figure 3).

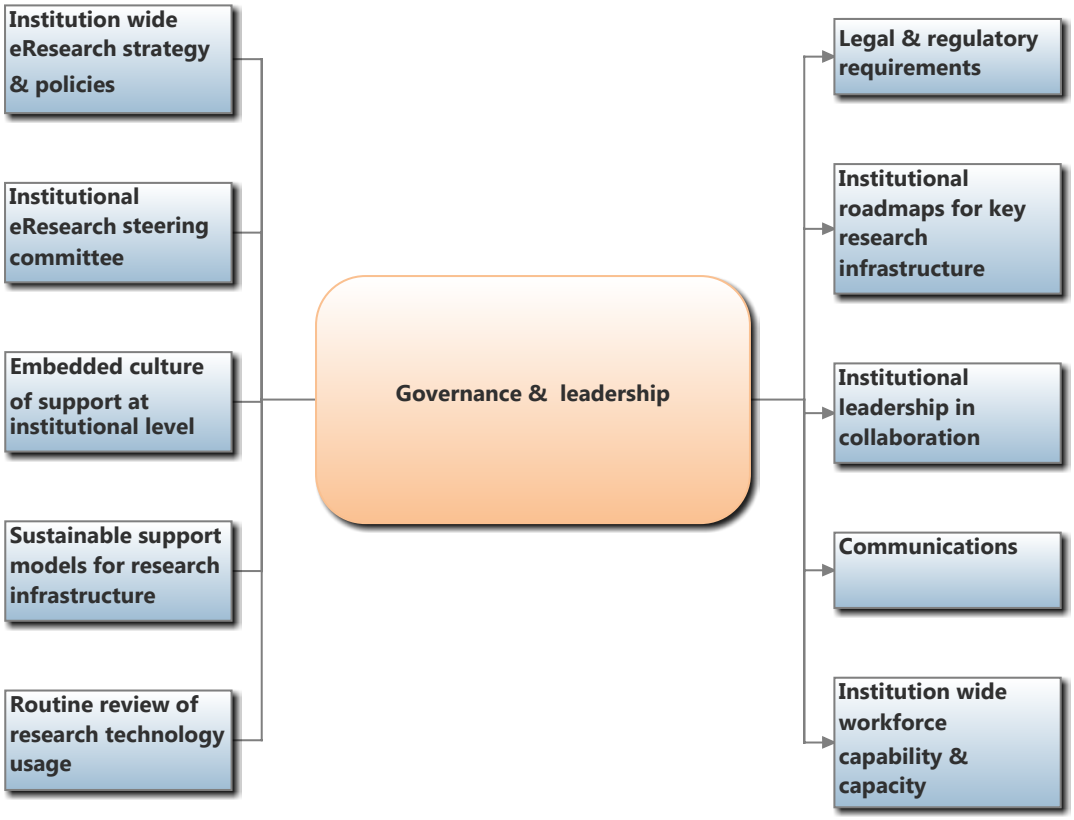

Figure 3. Governance and leadership dimension and subcomponents

Research Information and Data Management

This dimension is concerned with provision of specialist guidance and services to researchers and research groups from the inception of a research proposal through the research lifecycle from grant application, project start up, data collection, analysis and computation through to archiving, digital preservation and re-use. It includes data management planning, risk management, legal and institutional compliance with IPR, contractual obligations and sustainability planning for maintenance over the long-term. The subcomponents of this dimension can be seen in Figure 4. It focuses on the information, data and processes used within and as outputs of the research activity. The term "research data management" has been used extensively in the literature and has numerous definitions in regards to scope. Information Management has been coupled with data management in this model to ensure it is not confused with current definitions of Data Management. In addition it was felt information management implied a more continuous process and reliance on underlying knowledge, systems and processes.

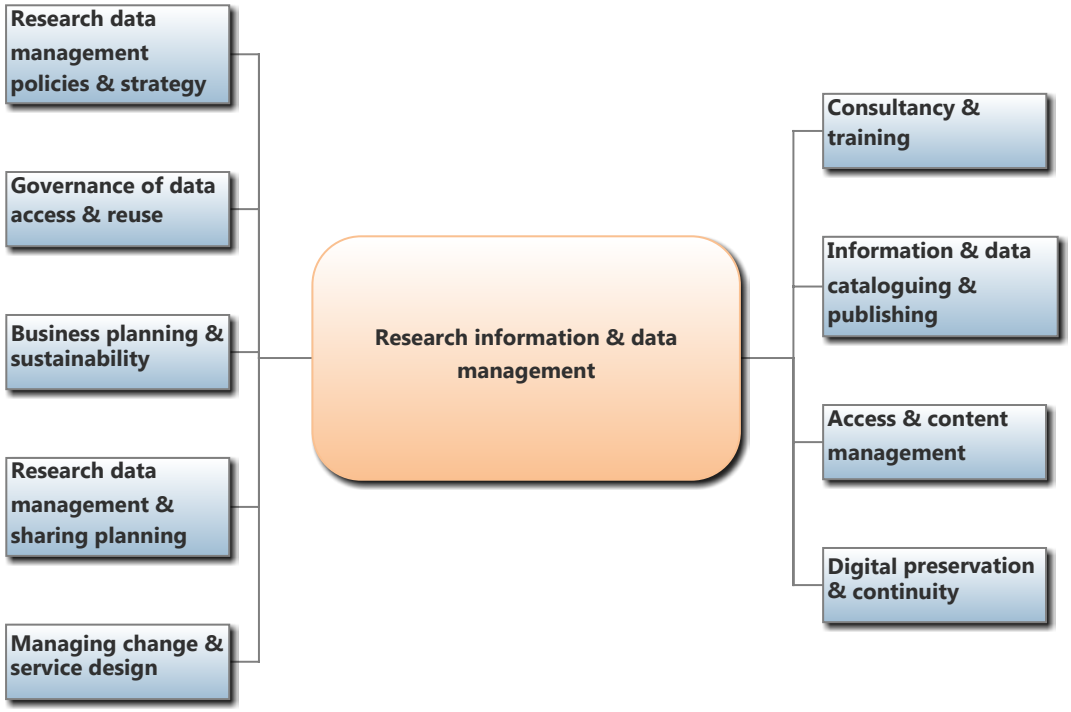

Figure 4. Research information and data management dimension and subcomponents

Technological infrastructure

The Technological infrastructure dimension covers the provision, support and awareness of e-Research applications, tools and hardware available through the institution and includes facilitating the use of cloud infrastructure. Figure 5 below denotes there are components of core underlying infrastructure (e.g. networks, identity management) and research specific infrastructure (e.g. HPC and virtual laboratories). It was also felt that there is a compliance and legal component to be included in this dimension. For example if ethics or research practices require secure storage to hold private health data then there is an institutional requirement to ensure a solution exists. The reasoning behind this approach is that in many instances the institution is the custodian/owner of the data collected and will therefore be held responsible for data loss or breaches of privacy.

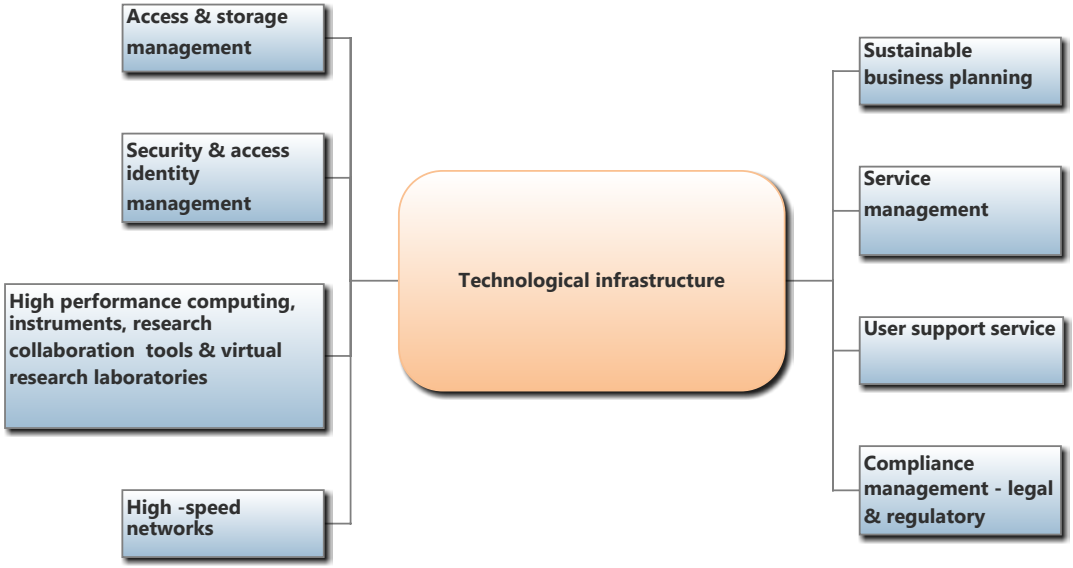

Figure 5. Technological infrastructure dimension and subcomponents

Collaboration and community engagement

This dimension focuses on the effectiveness of mechanisms used by the institution to engage with researchers, faculty and the wider stakeholder community (Figure 6). Subcomponents are: a) communications and dissemination; b) collaboration cooperation and managing change; c) community needs analyses; d) benefits management; and e) facilitating communities of practice.
Activities in this dimension are:

- Promoting and enabling an awareness and understanding of the institutional and national e-Research strategy and delivery programs;
- Cross organisational unit collaboration in the delivery of research
- Increasing the uptake of research enabling technological infrastructure (whether provided by the institution or some other service provider),
- Communication of case studies demonstrating benefits
- Gathering an understanding of the needs of the research community and facilitating the sharing of knowledge and experience.
- Increase the utilisation of consultancy and outreach services both within the institution and available externally.

Figure 6. Collaboration & community engagement dimension and subcomponents

Workforce education training and development

This dimension focuses on workforce capability (Figure 7) in four subcomponents: a) building digital literacy, b) best-practice bibliometric & data impact practices; c) career pathway development and recognition; and d) special subject matter expertise. It firstly focuses on the availability of staff with the appropriate level of knowledge skills and expertise to deliver relevant and quality services to researchers, including specialist staff who can deliver both data management and technical services as well as having problem domain knowledge to work in specific research disciplines. The second focus is on professional development, education and training of researchers and professional staff: including staff from other areas of the institution e.g. research office staff.

Figure 7. Workforce education training and development dimension and subcomponents

Service delivery and management

This dimension focuses on the operations and performance of the e-Research support service for example, IT, Library and information services, with the aim of improving services offered to researchers and reporting on progress and outputs that add value to the institution (Figure 8).

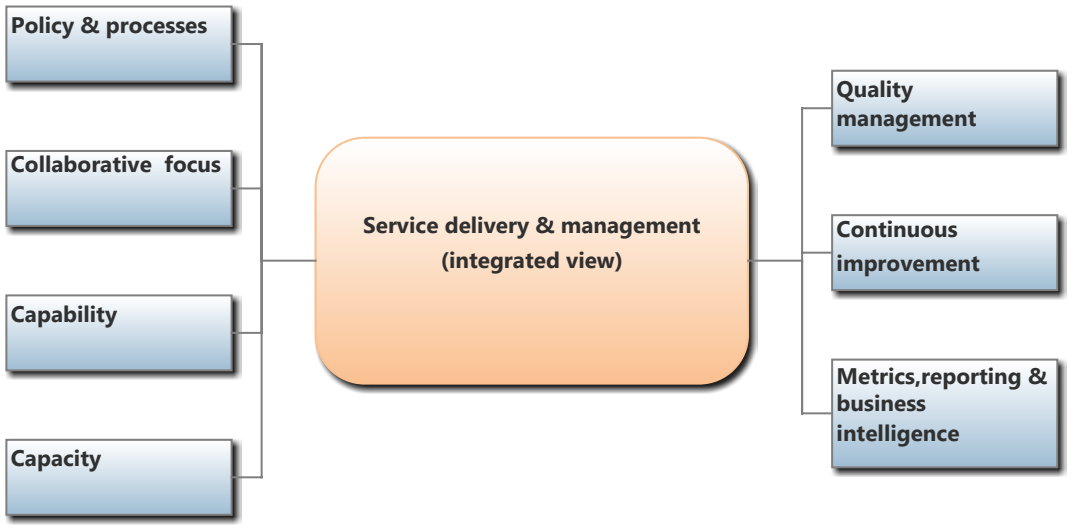

Figure 8. Service delivery and management dimension and subcomponents

The HWMD maturity model

As discussed earlier each dimension and subcomponent has a set of indicators that are measured in a self-assessment tool developed by the authors. The score assigned by the tool, as shown in the example in Figure 9, reflects the maturity level of the service, organisational unit or institution that has been self-assessed. The maturity levels 1-5 reflect increasing levels of capability and capacity encompassing human technical and environmental factors in the e-infrastructure for research space:

1 - Contemplating & commencing
2 - Investigating & identifying
3 - Planning & testing
4 - Implementing & monitoring
5 - Integrating & optimising.

The zero on the scale shows that the dimension indicators are not relevant for the service, organisational unit or institution being self-assessed.

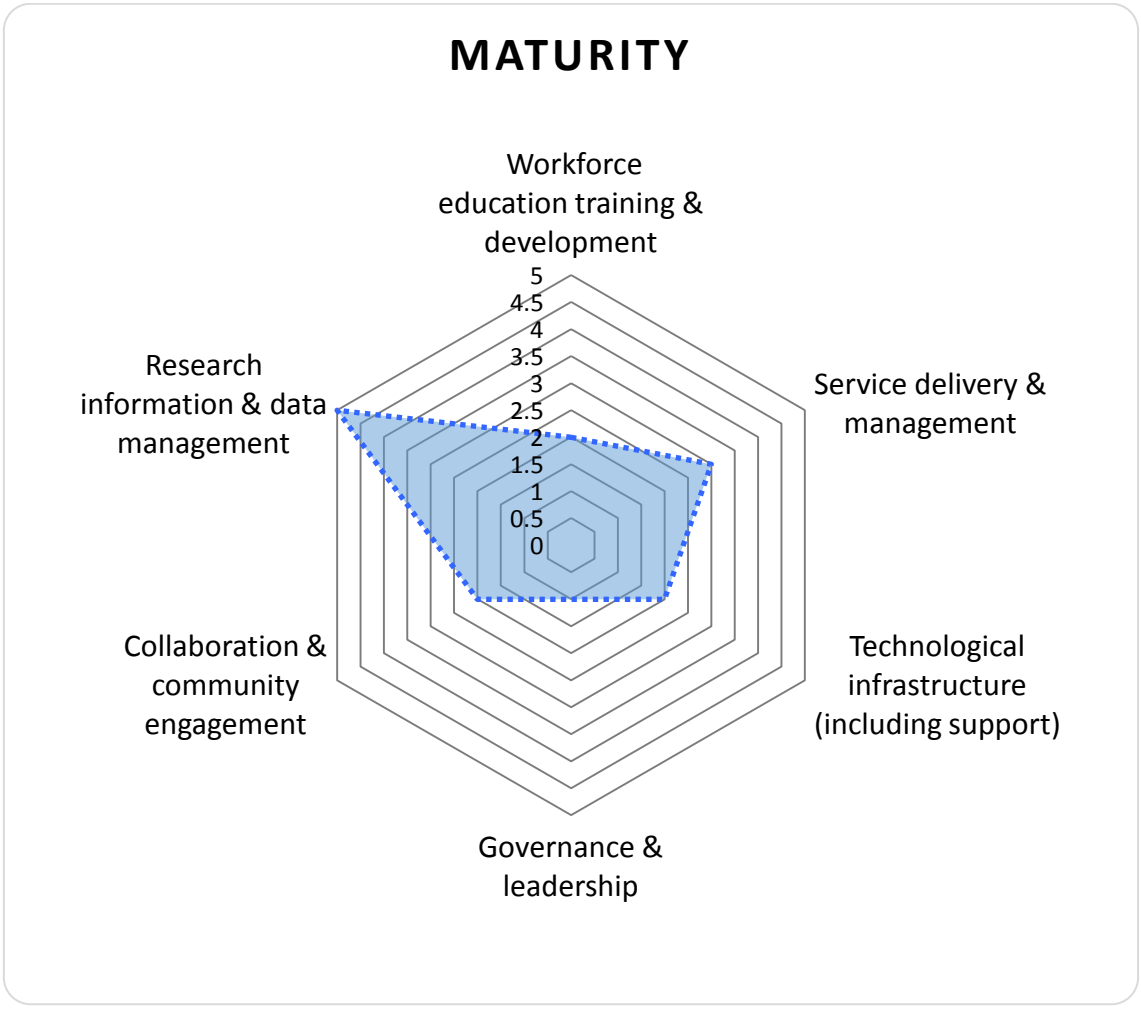

Figure 9. An example of a self-assessment scored in the HWMD maturity model

Figures 2- 8 above show subcomponents for each of the dimensions of the model. Examples of good practice indicators that institutions and organisational units could use to benchmark themselves against can be found in Table 2.

Table 2.
Selected examples of dimension subcomponents with institutional and service/organisational unit indicators

Dimension subcomponents	Institutional Indicator	Example service/organisational unit indicator (Likert Scale 1(Strongly disagree) to 5 (Strongly Agree))
Governance & Leadership		
Roadmap for key research infrastructure	The institution has a 5 year roadmap/plan for continuous development of research infrastructure.	Our service/organisational unit has a prioritised business plan to deliver key milestones with built in flexibility & responsiveness to respond to institutional demands Our service performance reports align closely with the objectives in the institutional research plan (or equivalent).
Collaboration in leadership	The institution has inter-disciplinary senior executive who together provide governance and leadership to the eResearch community.	Our service/organisational unit senior management team work collaboratively with other senior managers in the research infrastructure community both internal and external to the institution
Research Information & Data Management		
Data preservation and continuity	Institutional systems and services are established for managing research data for long-term (10 year+)	Our service/organisational unit manages and continually reviews data integrity, regulations and levels of access to ensure compliance with requirements; formats and file types are reviewed for risks of obsolescence.
Managing change & service design	The institution can identify its publicly funded research data holdings; risks are managed and policies and services monitor the need for change in provision.	Our service/organisational unit is rolling out liaison processes to ensure data assets, risks, and opportunities are identified and requirements for support are being met.

Technological infrastructure		
Service Management	The institution has formal service level/ operational level or equivalent agreements in place to monitor and manage agreed levels of service for research infrastructure including business continuity and disaster recovery plans.	Our service/organisational unit regularly monitors and reports on technological infrastructure usage by researchers & research groups.
High performance computing, hardware infrastructure, networks, collaboration technologies identity management, virtual research laboratories	The institution provides reliable, high-performance and economically efficient computational infrastructure, networks, virtual research environments, collaborative tools and other related services to researchers/research groups.	Our service/organisational unit provides institutional level specialist support 24/7 to researchers/research groups for HPC and other facilities and tools used by researchers
Collaboration & Community Engagement		
Facilitating communities of practice	The institution promotes communities of practice to bring benefits to facilitate organisational change.	Our service/organisational unit recognises and acknowledges that services, systems and infrastructure development is driven by the research community and participates in communities of practices.
Communications & Dissemination	The institution has a communications strategy and plan for communicating consulting and updating the community on eResearch infrastructure progress and other news and resources.	Our service/organisational unit regularly updates staff on the most recent e-research infrastructure development and they share that information with researchers/research groups via support and or consultancy.
Workforce Education Training and Development		
Building digital literacy	The institution provides research information & data management and e-Research tools and infrastructure training and development programs for postgraduate research students, staff and other researchers.	Our service/organisational unit meets training and development needs of PhD students, staff and researchers, and provides consultancy for researchers, research groups and other departments/units and research groups.
Career pathway development & recognition	The institution values e-infrastructures development and service provision contributions to research outputs through recognition of new emerging roles such as data scientists and data librarians.	Our service/organisational unit staff are named on research grant applications and publications when then partner with researchers/research groups.

Service delivery & Management		
Collaborative focus	The institution recognises and acknowledges that services, systems and infrastructure development are driven by the research community.	Our service/organisational unit collaborates in joint planning and reviews with other services engaged in e-Research infrastructure activities e.g. IT Library, Information management services, library, research office,
Metrics reporting and business intelligence	The institution has an integrated reporting model for eResearch services and infrastructure that gives senior executives a whole system view of progress and performance.	Our service/organisational unit regularly reports to senior executive on a portfolio of measures e.g.: usage by researchers/research groups; user support, service response times, consultancy

Summary findings

This model is useful as it cuts a clear path through the complexity of the operational, professional and political environment in which institutions and senior managers are attempting to navigate whilst partnering with the research community in an effective way to deliver valuable research outputs. The whole systems approach of this model focuses on operational quality and reliability, building capability and capacity to produce consistent value in the case of research outputs and assets. This approach helps to dismantle the perspective that enabling technologies and services are separate and an add-on to the core business of research.

Underpinning the model would be a self-assessment survey tool which prompts the user with a number of questions within each dimension/subcomponent. The responses to those questions determine the level of service maturity within each dimension.

Limitations

While this model has been developed from known information sources and authors' experiences in a systematic manner, it was undertaken within constrained timelines and the literature review of published studies and the grey literature was not exhaustive. However, the authors feel there is sufficient similarity in the research enabling technologies and capabilities identified in the papers for us to assume that the major themes and subthemes that are of concern to those working in this space have been identified. The work has been hampered by the lack of clarity and the difference in terminology used in papers and within the community itself. Nonetheless it is felt the key information has been extracted and distilled to inform debate and identify a way forward. It is acknowledged that further work needs to be done to research and synthesise all documents relating to this area. For instance, within some of the dimensions it was felt knowledge and experiences could have been drawn from other industry sectors to further the discussion.

Conclusion

There is a significant gap in available tools and measures that that can be used to gain a cohesive integrated view of e-research service provision within the institution from a socio-technical perspective. To date the focus in the literature has been on individual components and dimensions e.g. research data management, library support for research etc. As a result of this shortcoming, there are no existing methods for measuring performance of eResearch services delivery using a socio-technical view. The proposed model helps bridge that gap.

The information provided in this paper, combined with field site test feedback, will promote discussion and debate amongst the community and opportunities will present to gather input to optimise the model. The next steps would be to further elaborate and test the constructs and indicators of the model in field test sites and to develop a self -assessment survey tool.

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Appendix 1.

Definitions describing the domain of technology enabled research.

Source	Definition
JISC, 2006. Studying user priorities for a research e-infrastructure. Retrieved from http://www.jisc.ac.uk/news/studying-user-priorities-for-a-research-e-infrastructure-21-nov-2006	"e-Infrastructure is the term used for the distributed computing infrastructure that provides shared access to large data collections, advanced ICT tools for data analysis, large-scale computing resources and high performance visualisation. It embraces networks, grids, data centres and collaborative environments. In spite of its importance to the UK's research and science base, however, very few researchers currently consider e-infrastructure of benefit to their research. In spite of its importance to the UK's research and science base, however, very few researchers currently consider e-infrastructure of benefit to their research."
Research Council UK, 2008. Retrieved from http://www.rcuk.ac.uk/research/xrcprogrammes/prevprogs/	"e-Science (or e-Research) is the novel use of ICT to support existing and new forms of research during all of phases of its life cycle, across all disciplines from engineering to the humanities. The UK Research Council's e-Science programme, launched in 2001, aimed to give UK researchers a leading position in the development of "grid" technologies, research software and other e-infrastructures, which facilitate and enable research across all disciplines. The programme ended in 2008 and e-Science core programmes continue under the e-infrastructure programme."
Research Council UK, 2011. Retrieved from http://www.rcuk.ac.uk/research/xrcprogrammes/otherprogs/einfrastructure/	"e-Infrastructure refers to a combination and interworking of digitally-based technology (hardware and software), resources (data, services, digital libraries), communications (protocols, access rights and networks), and the people and organisational structures needed to support modern, internationally leading collaborative research be it in the arts and humanities or the sciences. This definition reflects a broader understanding of e-Infrastructure as defined in the report "Delivering the UK's e-Infrastructure for Research and Innovation."
Stewart, C.A. 2010. What is Cyberinfrastructure? Presentation. ACM SIGUCCS 2010 Annual Meeting, 24-27 October, Norfolk, VA. http://hdl.handle.net/2022/13987 .	"Cyberinfrastructure consists of computational systems, data and information management, advanced instruments, visualization environments, and people, all linked together by software and advanced networks to improve scholarly productivity and enable knowledge breakthroughs and discoveries not otherwise possible. "
European Commission, 2015. e-infrastructure reference group. Retrieved 5 March 2015 from http://e-irg.eu/start	"The term e-Infrastructure refers to this new research environment in which all researchers - whether working in the context of their home institutions or in national or multinational scientific initiatives - have shared access to unique or distributed scientific facilities (including data, instruments, computing and communications), regardless of their type and location in the world."

Bischel, 2012. Research computing: the enabling role of information Technology Research report. EDUCAUSE centre for applied research. Retrieved from http://net.educause.edu/ir/library/pdf/ERS1211/ERS1211.pdf	"Research computing is a) any service or infrastructure provided to faculty or research staff for the purpose of performing research at a higher education institution b) highly resource-intensive; demanding of computing infrastructure, hardware, software, and personnel"….
Australian Government, 2015. The Australian Research Data Infrastructure Strategy. Retrieved from http://docs.education.gov.au/system/files/doc/other/the_australian_research_data_infrastructure_strategy.pdf	"Research data infrastructure refers to a range of facilities, equipment or tools that serve research through data generation, manipulation, and access. Research data infrastructure includes data itself and relies on a skilled technical and research workforce for establishment, implementation, operation and use." p.3
Australian Government, 2015. The Australian Research Data Infrastructure Strategy. Retrieved from http://docs.education.gov.au/system/files/doc/other/the_australian_research_data_infrastructure_strategy.pdf	"This definition of Research Infrastructures, including the associated human resources, Covers major equipment or sets of instruments, in addition to knowledge-containing resources such as collections, archives and databanks. Research Infrastructures may be "single-sited", "distributed", or "virtual" (the service being provided electronically). They often require structured information systems related to data management, enabling information and communication. These include technology based infrastructures such as Grid, computing, software and middleware". p.4

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