Usable, In-Use, and Useful Research:
A 3U Framework for Demonstrating Practice Impact

Shan L. Pan
shan.pan@unsw.edu.au
University of New South Wales, Sydney, Australia

L. G. Pee
peelg@ntu.edu.sg
Nanyang Technological University, Singapore

Abstract

In addition to innate curiosity, many of us also see scientific research as a way of making the world a better place. There has been a drive to better understand and observe the practical and societal impact of research, led by researchers seeking to find meaning and purpose in their work, as well as government agencies responsible for allocating research funding to maximum effect. Despite a wealth of guidance from researchers discussing impact and agencies evaluating impact, making practice impact visible and demonstrable remains arduous to researchers because it appears to be possible only at the end of a long and winding pathway to impact. This article presents a framework for demonstrating practice impact as it is being realized progressively, rather than only at the end of the pathway. It identifies *usable, in-use*, and *useful* research outputs, with each having cumulative and demonstrable practice impact. Our analyses of the guidelines of existing impact evaluations and top-ranked impact cases submitted to REF show that all three forms of impact can be demonstrated and are recognized as practice impact. Framing impact in terms of "use" inherently connects the perspectives of researchers and beneficiary users and positions users as co-producers of impact rather than passive objects and recipients of research. The 3U framework is descriptive as well as prescriptive. It identifies impact indicators for each form of impact. It also indicates the necessary actions for strengthening impact. When applied iteratively, the 3U framework facilitates the identification and pursuit new research questions that will further solidify a research endeavor's practice impact.

Keywords: Practice impact, societal impact, research relevance, translation, engaged scholarship, co-creation, usefulness

Usable, In-Use, and Useful Research:
A 3U Framework for Demonstrating Practice Impact

1. Introduction

Most, if not all of us, are motivated by the aspiration that our research will make a real difference in the world we live in. Making our practice impact (henceforth "impact") visible is one of the most cogent means of observing the outcomes of our work, communicating the value of research, and convincing funders the necessity of continuously investing in research. In fact, demonstrating practice impact is increasingly weighted in government and institutional funding decisions worldwide. Many funding agencies now require a clear pathway-to-impact statement in grant proposals; some have conducted impact evaluations regularly, such as Australia's Engagement and Impact Assessment (EI), Italy's Research Quality Evaluation (VQR), Netherlands's Standard Evaluation Protocol (SEP), and United Kingdom's Research Excellence Framework (REF). These evaluations take a pluralist perspective of impact and define it in terms of an effect on, change, or benefit to the economy, society, culture, public policy, public services, health, environment, or quality of life, beyond the contribution to academic research.

Information systems (IS) researchers also increasingly recognize the need to make a visible practice impact (Agarwal and Lucas 2005; Davison and Bjørn-Andersen 2019; Galletta et al. 2019; Nunamaker et al. 2015; Nunamaker et al. 2017; Swanson 2014; Wiener et al. 2018). As an academic discipline, the lack of demonstrable practice impact will eventually jeopardize our identity and viability (Agarwal and Lucas 2005; Nunamaker et al. 2017; Swanson 2014). Business school accrediting bodies such as the Association to Advance Collegiate Schools of Business (AACSB) and the European Foundation for Management Development (EFMD have revised their standards with impact at the core of business schools' missions. In an international study, the chair of AACSB's board of directors concluded that "in the future, business schools will have to be more strategic about their research investments and more explicit about assessing the return – not because AACSB will require it, but because stakeholders are starting to demand it" (2012, p. 4). The study recommends that future accreditation requires business schools to report their practice impact.

Whether for personal or professional reasons, many of us are striving to demonstrate at least some portions of our practice impact as responsible researchers (Burget et al. 2017). Despite a wealth of guidance from researchers discussing practice impact and agencies conducting impact evaluations, demonstrating impact remains arduous. Questions that frequently arise among researchers include:

1) What constitutes practice impact?

A myriad of definitions for impact exist in IS and non-IS publications and there is not yet a universally accepted definition (Wiener et al. 2018).

2) How to demonstrate impact?

Many different impact measures and indicators have been suggested and reported in impact evaluations. Determining the appropriate ones and gathering data can be challenging in itself. Most impact evaluations require researchers to present factual, verifiable, and externally referenced evidence of impact. For example, REF requested the upfront submission of corroborating evidence along with impact case studies narrating the reach and significance of impact achieved (United Kingdom Research and Innovation 2019). Australia's EI states, in the submission guidelines, that "the description of the impact should be driven by explicit evidence, for example cost-benefit analysis, or adoption of public policy that leads to changes in behaviour" (Australian Research Council 2018a, p. 19).

3) How to manage research endeavors to make a visible impact?

Impact can only manifest in practice. Yet, practitioners generally do not read or understand academic journals (Nunamaker et al. 2017). Demonstrating impact requires researchers to traverse the "last research mile", that is, to go beyond assuming that proof-of-concept prototypes will generate value as a matter of course, and conduct more sophisticated proof-of-value research to ascertain and maximize research value (Nunamaker et al. 2015). There is often a time lag between research and practice impact (Niederman et al. 2015). Impact appears to be visible only at the end of the pathway to impact, which can be long and winding. The significant resource, time, and effort required seem like an insurmountable gap to many researchers.

This article first consolidates existing understanding of what impact is by reviewing definitions of impact in both IS publications and the broader literature to identify the key features and provide a working definition. The review indicated an opportunity to understand impact based on the notion of use and inspired a framework that identifies three cumulative forms of impactful research outputs: usable, in-use, and useful. Analyses of existing impact evaluations and top-rated impact case studies submitted to REF 2014 show that all three forms of impact can be demonstrated and are recognized as practice impact. The 3U framework suggests an incremental approach to demonstrate impact earlier, rather than only at the end of the pathway to impact.

2. What constitutes Practice Impact?

To understand practice impact, we collected definitions or descriptions from IS publications as well as highly cited articles in non-IS publications. We observed that most non-IS publications adopted the definitions of impact in national impact

evaluations such as REF (e.g., Bornmann 2013; Ozanne et al. 2017; Penfield et al. 2014) so they were analyzed instead. All definitions were coded using the constant comparative method (Strauss and Corbin 1997), which is an iterative process of categorizing units of text (e.g., nouns, concepts) qualitatively until no new categories are necessary. Four themes that clarify practice impact emerged in both non-IS (see Table 1 for summary and Table 4 in the Appendix for details) and IS publications (see Table 2 for summary and Table 5 in the Appendix for details):

1) What does impact mean? Research's benefit beyond academia
2) Impact on who? Different stakeholder groups (e.g., individuals, businesses, communities)
3) How to generate impact? Interact with stakeholders (e.g., engagement, diffusion, valorisation)
4) How to measure impact? Select relevant and observable indicators

Table 1. Themes in Definition/Description of Impact in National Impact Evaluations

Study	What does impact mean?	Impact on who?	How to generate impact?	How to measure impact?
Royal Netherlands Academy of Arts and Sciences (2009)	✓	✓	✓	✓
Research Excellence Framework (2012)	✓	✓		
Italian National Agency for the Evaluation of the University and Research Systems (2015)	✓		✓	✓
Australian Research Council (2018b)	✓	✓		

Table 2. Themes in Definition/Description of Impact in IS Publications

Study	What does impact mean?	Impact on who?	How to generate impact?	How to measure impact?
Agarwal and Lucas (2005)	✓	✓		✓
Swanson (2014)			✓	
Bichler et al. (2015)				✓
Niederman et al. (2015)	✓	✓		
Nunamaker et al. (2015)			✓	✓
Lee (2016)	✓	✓	✓	
Nunamaker et al. (2017)		✓		
Wiener et al. (2018)	✓	✓	✓	✓

The first two themes are present in almost all definitions, indicating that generating benefit and identifying beneficiary stakeholder groups beyond the academia are the dominant elements of practice impact. Practice impact is based on research that is relevant and useful to stakeholders who consume research, such as citizens, funding agencies, practitioners, and venture capitalists (Wiener et al. 2018). Some ways that useful knowledge flow to stakeholders in the society includes: (1) Students carry ideas and skills to jobs in industry, government, and the nonprofit sector; (2) Researchers publish results in journals, which are read by users in the public and private sectors; (3) Researchers present their ideas at conferences, seminars, and other events that bring them into contact with potential users; (4) Industry sponsors a focused research project by researchers; (5) Groups of companies and researchers collaborate in cooperative research projects; (6) Researchers enter into an individual consulting arrangement with a company; (7) Researchers engage in entrepreneurial ventures that do not involve university-owned intellectual property; (8) University licenses intellectual property to a private firm or spins off a startup company (Swanson 2014, p. 307). Research groups that have generated strong practice impact "explicitly focus on doing 'useful' research; they receive substantial funding from industry for joint projects, which indicates that industry finds their work valuable; and they produce books and reports that are widely read outside academia" (Wiener et al. 2018, p. 472).

Definitions in IS publications tend to be more specific about impact measurement indicators, citing examples such as cost and revenue, tools and methods, new forms of business, and publications in practitioner journals. They might reflect the indicators that are considered especially relevant to IS research, though they have been adopted by many other disciplines as well. A key distinguishing purpose of IS as a field is to improve the ways people create value with information (Nunamaker et al. 2015). The two (out of eight) definitions that account for this purpose focus on the impact of IT on the larger system in which it is embedded (e.g., IT's effect on cost structure; Agarwal and Lucas 2005) or the impact of IS (e.g., IT-based businesses' impact on society; Lee 2016). IS research can create impact by improving or addressing challenges in IT applications or by developing IS as solutions to challenges in other domains. However, even in articles that have defined practice impact in terms of information, a variety of impact indicators beyond informational value are cited.

Overall, definitions of practice impact in IS research appear to be conceptually similar to general definitions. Based on this review, a working definition of practice impact encompassing the four common themes is:

Practice impact is the observable benefit of research on relevant stakeholder groups beyond academia, such as individuals, organizations, communities, industries, or economies, generated through interactions with them and measured with observable indicators.

Relevance to practice is often mentioned in discussions of practice impact (seven of the eight IS articles and three of the four impact evaluations). Although relevance and impact are both important, they refer to different aspects of research. Relevance is indicated by the importance, accessibility, and suitability of a research output's content, such as research model or publication (Benbasat and Zmud 1999; Rosemann and Vessey 2008). Importance refers to whether the content addresses a real-world issue in a timely manner; accessibility is the extent to which the content is understandable, readable, and focuses on results rather than the research process; suitability is whether the content is appropriate for application in practice. Importance, accessibility, and suitability are primarily influenced by the researcher's design decisions (e.g., problem framing) and indicate a research output's *potential* to generate practice impact. In contrast, practice impact is observable change in beneficiaries. Relevance, therefore, is a necessary but not sufficient condition for generating practice impact. Relevant research has potential societal value that might not be impactful, even in the long term.

3. How to Demonstrate Impact? The 3U Framework

The preceding review indicates that practice impact is experienced by beneficiaries beyond academia, through interacting with relevant stakeholders and putting research outputs to practical use. It is necessary to "develop a sense of – and an approach to – ways in which the research one works on might or will ultimately be useful" (Wiener et al. 2018, p. 26). Australia's EI "aims to encourage greater collaboration between universities and research end-users, such as industry, by assessing engagement and impact" (Australian Research Council 2018b, p. 5). Netherland's impact evaluation considers "commercial or non-profit use of research results and expertise" to be one of the key aspects (Royal Netherlands Academy of Arts and Sciences 2009, p.10). The majority of indicators provided by UK's REF also focuses on adoption or implementation of research outputs in health, society, economy, commerce, etc. (Research Excellence Framework 2012). For research, traversing the last mile contributes to relevance as well as rigor, as "an interesting idea for a new solution will contribute very little to scholarly knowledge and will make little impact on society until someone takes it through the last research mile. A research community's understanding of a problem domain will remain rudimentary until it has moved solutions through the last research mile. Proof-of-concept technologies are impoverished compared to the proof-of-use systems" (Nunamaker et al. 2015, p.40).

Framing impact in terms of use presents an opportunity to address the challenges of demonstrating practice impact, i.e., determining appropriate indicators and navigating the chasm between research and practice impact. We offer a "3U" framework that identifies three cumulative forms of impactful research outputs. In essence, "usable" research outputs are translated and ready for practical application,

making an impact by increasing beneficiaries' awareness and knowledge of affordances available for improvement. "In-use" research outputs are transferred for appropriation in practice and their impact lies in mobilizing actions towards improvement. "Useful" research outputs make a transformational and observable impact on the bottom line or aspects that beneficiaries seek to improve. As detailed in the following sub-sections, all three forms of impact are implicitly recognized in existing impact evaluations with guidelines listing corresponding measurement indicators. The three forms of impact are also prevalent and recognized in practice, as our analysis of top-ranked impact case studies submitted to REF 2014 in section 3.5 indicates. The 3U framework shows how practice impact can be demonstrated earlier, rather than only at the end of the pathway to impact. By focusing on the notion of use, the framework bridges the gap between research and practice impact as it orientates researchers towards making their research outputs more usable and practitioners towards visualizing how research outputs can be useful means to their ends. This also helps to develop a sense of shared responsibility between researchers and practitioners that propels the realization of practice impact. Usable, in-use, and useful research outputs and their impact indicators are detailed next.

3.1 Usable Research Output

Usable research outputs refer to those that have an impact by way of translating research findings into a practically applicable form and disseminating them. Examples of usable research outputs include intervention strategies, implementation guidelines, toolkits, policy briefs, infographics, decision recommendations, solution products, or value-adding services. They are often a synthesis of findings from a programme or body of research rather than findings reported in a single journal article, packaged in a way that is actionable. They embody or incorporate research findings and offer visible affordances for solving problems or improving conditions. Dissemination can be formal or informal, through channels such as practitioner-oriented publications, websites, social media, outreach events, public lectures/presentations, field visits, emails, or private meetings. It is necessary to consider the users' perspective and tailor the communication of research outputs in a manner that they will relate – who are they, what are their needs, how can they use the research outputs to improve an aspect of interest? For instance, we have created infographics highlighting actionable strategies for designing professional knowledge work involving robots with artificial intelligence and for managing online co-creation communities, based on our research findings (reference omitted for blind review). They are posted on social media, university websites, and shared with our industry contacts.

Usable research outputs make an impact by informing potential beneficiaries, increasing their awareness and knowledge of the solution options available or potential improvements (Given et al. 2015; McNie et al. 2016). REF acknowledges

such informational impact, such as research leading to debates:

> "[T]here may be impact arising from research which take forms such as holding public or private bodies to account or subjecting proposed changes in society, public policy, business practices, and so on to public scrutiny. Such holding to account or public scrutiny may have had the effect of a proposed change not taking place; there may be circumstances in which this of itself is claimed as an impact. There may also be examples of research findings having been communicated to, but not necessarily acted upon, by the intended audience, but which nevertheless make a contribution to critical public debate around policy, social or business issues." (Research Excellence Framework 2019, p. 54)

Similarly, IS researchers acknowledge that research has no impact until it informs practice (Nunamaker et al. 2017). Niederman et al. (2015) suggest that IS researchers should act to recognize the significant amount of new and practical knowledge created in IS, to better package and promote IS research results, theories, and lessons to achieve research impact. For example, generating content directed towards IS practice constitutes a form of impact that occurs through "preparing individuals for professional practice, and practitioners as professionals seek specialized knowledge and accreditation that affirms and confirms their practice in the public interest" (Swanson 2014, p. 307). Robey and Markus (1998) argue that IS research can be made more consumable by practitioners, through adjusting the way research is presented and disseminated. They provided insightful suggestions for crafting research reports in an accessible style and incorporating a novel and constructive story line. Researchers can also consider publishing in practitioner-oriented journals such as Sloan Management Review.

Existing impact evaluations are replete with indicators measuring the extent to which research outputs are usable. They tend to focus on the effort expended on translating and disseminating research findings into usable research outputs and the attention generated (see Table 6). Effort-oriented indicators that have been identified in guidelines of impact evaluations include number of public events held and budget used for outreach (Bornmann et al. 2018; Grant 2015). IS researchers have also suggested indicators such as patents filed and commercialization of products/services (Wiener et al. 2018). Attention-oriented indicators include number of event attendees, public media coverage or debates (Research Excellence Framework 2019), as well as social media mentions, shares, and comments (Bornmann and Haunschild 2018; Grant 2015; Vertigo Ventures and Digital Science 2016).

3.2 In-Use Research Output

In-use research outputs refer to those that generate impact as they are transferred for appropriation in practice. Research outputs can be brought to bear on users'

decisions, behaviors, activities, practices, and processes. In general, research outputs can be put into use in three ways: instrumental, conceptual, or symbolic/legitimative (Beyer 1997; Moeini et al. 2019). Instrumental uses involve applying research results in specific, direct ways and include decision making tools, benchmarks, and forecasts. Conceptual uses involve utilizing research results for general enlightenment in a way that influences action, albeit less directly and less specifically than in instrumental uses. Examples include a theory or linguistic construct applied to understand decision situations or contingent actions. Symbolic/legitimative uses involve employing research results to legitimate and sustain predetermined positions. For example, research findings can be used by practitioners to justify and rationalize their investments.

Users who adopt research outputs do so with some confidence that it will generate desirable benefit eventually. Even though the expected benefit is not yet clearly observable, in-use research outputs generate a practice impact as they set users in motion towards improvement. For instance, it was observed in a research project that adoption of the proposed intelligent tutoring system served as a vehicle for change by "first introducing cultural change in schools and shifting inertia around dyslexia" (Gooch et al. 2017, p. 384). Similarly, the Academic Research Impact Model proposed by Swanson (2014) considers both initial and successive adoption of research outputs by practitioners in the field to be forms of impact. The impact of research-in-use is highlighted in the theory of translation, which posits that impact is enabled by mobilization that involves changes in adoption scale or in learning processes, resulting in a horizontal scaling up as more users adopt, or vertical scaling up as the diversity of adopters increase (Joly et al. 2015).

Indicators for the practice impact of in-use research can be found in the guidelines of existing impact evaluations. The extent to which research outputs are being used is typically measured in terms of the breadth and depth of adoption. Breadth-oriented indicators focus on the diversity of adopters, which is in line with REF's measure of reach, "understood as the extent and/or diversity of the beneficiaries of the impact, as relevant to the nature of the impact. Reach will be assessed in terms of the extent to which the potential constituencies, number or groups of beneficiaries have been reached; it will not be assessed in purely geographic terms, nor in terms of absolute numbers of beneficiaries" (Research Excellence Framework 2019, p. 52). In contrast, depth-oriented indicators focus on the number of adopters or their engagement in shaping and refining the research output in use, such as product sales, number of licensees, and user' involvement throughout research (see Table 7).

3.4 Useful Research Output

"Useful" research outputs make a transformational and observable impact on the bottom line or aspects that beneficiaries seek to improve. Useful research outputs are near the end of their pathway to impact and their value is clear from the beneficiaries' perspective (see Figure 1). They improve beneficiaries' efficiency and/or effectiveness significantly. This is the strongest form of practice impact that impact evaluations such as REF and EI seek to promote ultimately. Similarly, IS researchers often consider useful research outputs when discussing practice impact. Wiener et al. (2018) recognize that research outputs need not be immediately useful, but researchers seeking to achieve practice impact should develop a sense of – and an approach to – ways in which research outputs might or will ultimately be useful. Nunamaker et al. (2015) argue that true societal impact can only manifest in practice and it is necessary to go beyond proof-of-concept prototypes to develop proof-of-use systems in order to realize impact and maximize the value of research. Agarwal and Lucas (2005) have called for more macro IS studies focusing on the transformational aspects of information technology to visibly communicate research impact and significance to individuals, organizations, industries, and the economy.

Indicators for useful research outputs in existing impact evaluations focus on beneficiaries' efficiency and effectiveness (see Table 8). The indicators are different from those measuring in-use research outputs (discussed in section 3.2) in that they focus on evident changes following adoption. Efficiency indicators account for the resources used (e.g., time and cost), and is highest when maximum results are achieved with a given level of resources, or minimal resources are used to achieve a certain level of result. Effectiveness indicators measure the extent to which the actual results match expectations. Existing indicators include financial performance and improved sustainability. Usefulness of research outputs have been measured both quantitatively or qualitatively. For example, changes to policies, legislation, and codes of practice can be supported with qualitative documentary evidence.
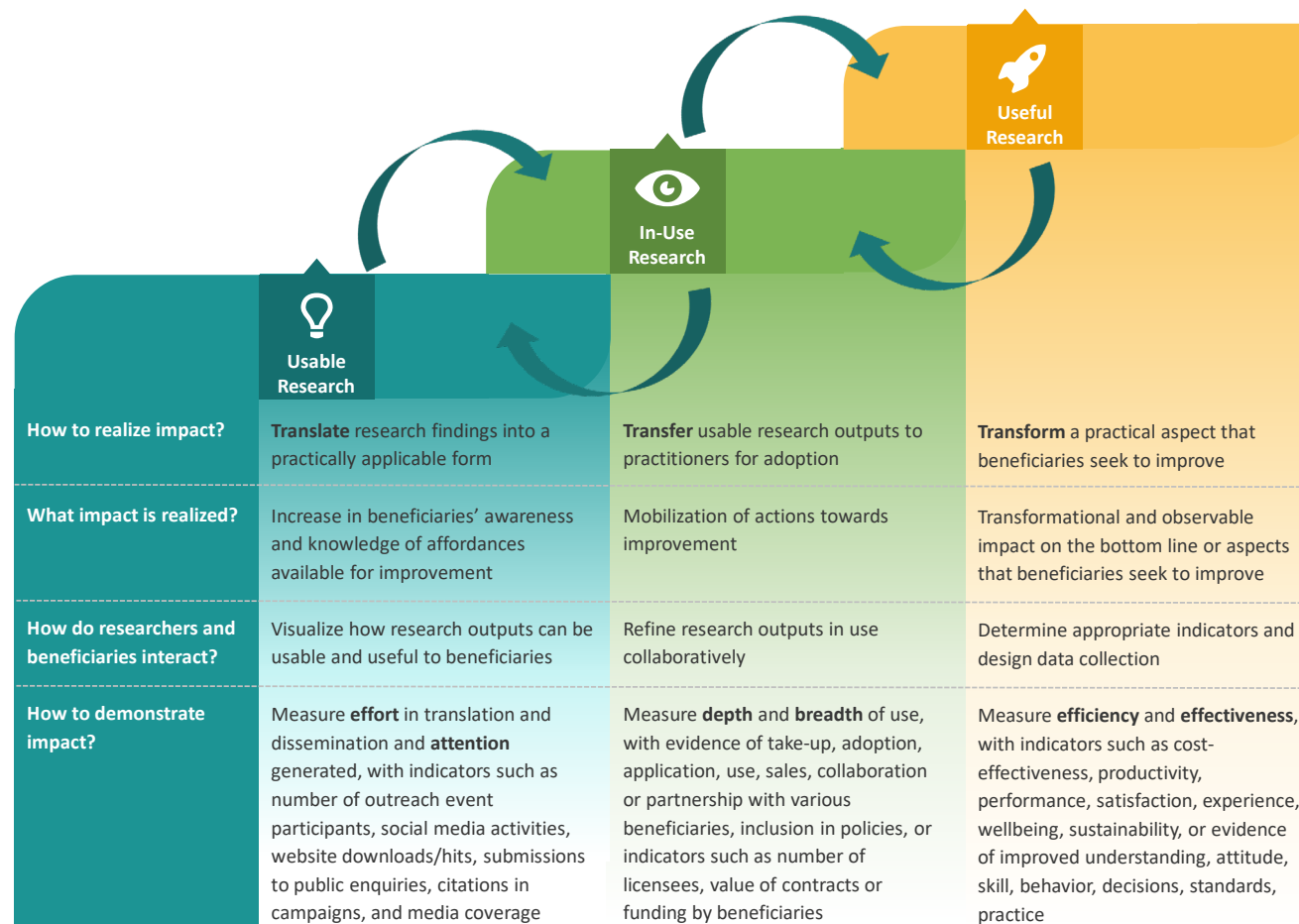
	Usable Research	In-Use Research	Useful Research
How to realize impact?	**Translate** research findings into a practically applicable form	**Transfer** usable research outputs to practitioners for adoption	**Transform** a practical aspect that beneficiaries seek to improve
What impact is realized?	Increase in beneficiaries' awareness and knowledge of affordances available for improvement	Mobilization of actions towards improvement	Transformational and observable impact on the bottom line or aspects that beneficiaries seek to improve
How do researchers and beneficiaries interact?	Visualize how research outputs can be usable and useful to beneficiaries	Refine research outputs in use collaboratively	Determine appropriate indicators and design data collection
How to demonstrate impact?	Measure **effort** in translation and dissemination and **attention** generated, with indicators such as number of outreach event participants, social media activities, website downloads/hits, submissions to public enquiries, citations in campaigns, and media coverage	Measure **depth** and **breadth** of use, with evidence of take-up, adoption, application, use, sales, collaboration or partnership with various beneficiaries, inclusion in policies, or indicators such as number of licensees, value of contracts or funding by beneficiaries	Measure **efficiency** and **effectiveness**, with indicators such as cost-effectiveness, productivity, performance, satisfaction, experience, wellbeing, sustainability, or evidence of improved understanding, attitude, skill, behavior, decisions, standards, practice

Figure 1. 3U Framework of Practice Impact

3.5 Applying the 3U framework of Practice Impact to IS Research

The 3U framework identifies three forms of impactful research output. Their impact is cumulative and the framework allows practice impact to be demonstrated earlier, rather than only at the end of a pathway to impact. We have shown that all three forms are generally accepted as practice impact, to the extent that existing impact evaluations have recommended corresponding measurement indicators. To understand their prevalence in actual IS research, we also analyzed actual impact cases submitted to REF 2014. An impact case is a narrative that describes how research resulted in a change, had an effect on or benefited stakeholders outside academia using qualitative and quantitative evidence.

To identify high-quality cases, we focused on those submitted by institutions scored highly by REF, since REF did not publish the impact score of individual cases. The following screening criteria were used to select high-quality cases:
- Subject-based unit of assessment is "Computer Science & Informatics", "Business and Management Studies", or "Communication, Cultural and Media Studies, Library and Information Management" (there is no "information systems" unit; total 872 cases)
- The submitting institution is top five in terms of impact rating score (maximum score is four; total 56 cases)
- The case describes the impact of information systems involving people. Cases that describe computer hardware/software development and computational approaches were excluded.

The screening resulted in nine cases. We observed that all the cases identified usable, in-use, as well as useful research outputs when detailing the impact (see Table 9). All the cases highlighted impact related to a tool/product/service embodying research findings, adoption and use, and observable changes to beneficiaries' performance. They also show that developing usable research outputs is vital – adoption and use hardly occur in the absence of usable artifacts.

The analysis also shows concrete examples for each type of research output. Usable IS research outputs that have been impactful ranged from budget models, reports for practitioners, methods for managing data and information, to software and system; These usable IS research outputs have been put into use by businesses, government agencies, non-governmental organizations, as well as individuals; They have been useful in shaping government policies, agendas, and standards, reducing risks, errors, and costs, and improving productivity, revenue, innovation, and decisions.

The analysis indicates that the 3U framework is applicable to critical research as well. Critical research often challenges the status quo by exposing societal inequities and power differentials (Guba and Lincoln 1994). Critical research in IS is concerned

with "social issues such as freedom, power, social control, and values with respect to the development, use, and impact of information technology" (Myers and Klein 2011; p. 17). Impact evaluations could favor research that lends itself more easily to societal uptake and inadvertently squeeze out critical research. One of the top-ranked impact cases we identified indicates that the practice impact of critical research can be demonstrated, is being recognized in impact evaluations, and is adequately captured by the 3U framework. Specifically, the impact case study submitted by Goldsmiths' College details the impact of critical research on the issue of human rights online. The research led to debates around Internet governance and telecommunications regulations, revelations of widespread illegal state surveillance of online communications, articulation of human rights and principles for the online environment, and initiatives to promote human rights issues online. It has drawn the attention of stakeholders such as policymakers, pundits, and media watchdogs around the world. Usable, in-use, and useful research outputs and their impact are identified in the case. The research has been translated into reports and presentations for practitioners such as policy makers (i.e., usable research output); The Brazilian government, the Swedish government, the Council of Europe, and NGOs such as European Digital Rights have drawn upon the research outputs to shape and steer debates about human rights in international and national legal and regulatory frameworks (i.e., in-use research outputs); The research has reframed the debate, and kept the internet governance and ICT for Development agendas accessible to human rights concerns (i.e., useful research outputs).

3.6 Making the 3U Framework Usable

Like other conceptual frameworks, the 3U framework has the potential of generating practice impact and is more likely so if it is made usable. To facilitate its practical application by researchers seeking to demonstrate impact, checklist, guidelines, tools, and trainings embodying the 3U framework could be developed. Here, we present a checklist of key issues to consider in the design of usable, in-use, and useful research outputs. The checklist serves to support researchers in visualizing the accumulation of impact and ensure that impact can be demonstrated with clear evidence. Based on the 3U framework, the checklist questions seek to shift researchers' perspective towards that of practitioners, so that they can begin to connect and co-create impact. Checklist questions related to usable research outputs focus on the effort to translate research findings and attention generated, while those related to in-use research outputs emphasize the depth and breadth of use and those for useful research outputs aim at increasing beneficiaries' efficiency and effectiveness (see Table 3). Measurement indicators for these are listed in Table 6, Table 7, and Table 8 and relevant indicators should be selected with input from users.

Table 3. Checklist Questions for Designing Usable, In-Use, and Useful Research		
Type of Research Output	Focus of Impact Indicators	Checklist Questions
Usable	Effort to translate research findings for users	• Have all the target beneficiary/user groups of research outputs been identified? • To what extent are research outputs translated into forms (e.g., checklist, guidelines, recommendations, tools, products) that can be readily used? • To what extent is practical guidance for using research outputs provided?
	Attention generated among potential users	• To what extent are research outputs promoted/marketed to target users (e.g., via social media)? • To what extent is the practical value of research outputs communicated to target users? • To what extent are research outputs readily available to target users (e.g., available on the Internet)?
In-Use	Depth of use	• Are research outputs being adopted and used by a significant proportion of target users? • Are research outputs frequently used by target users? • To what extent is a significant percentage of users engaged in providing feedback for refining research outputs?
	Breadth of use	• Are research outputs being adopted and used by a variety of target users? • Are research outputs being used for a variety of purposes? • To what extent is a variety of users engaged in providing feedback for refining research outputs?
Useful	Efficiency improvement for users	• To what extent are users involved in specifying efficiency indicators? • Are users involved in accessing efficiency data? • To what extent do research outputs significantly reduce cost or increase productivity?
	Effectiveness improvement for users	• To what extent are users involved in specifying effectiveness indicators? • Are users involved in accessing effectiveness data? • To what extent do research outputs significantly improve quality or performance?

4. Conclusion

The 3U framework identifies three forms of impactful research outputs and foregrounds the cumulative nature of practice impact. Our analyses of the guidelines of existing impact evaluations and top-ranked impact cases submitted to REF 2014 show that all three forms can be demonstrated and are recognized as practice impact.

Illuminating the structure among them indicates an incremental approach to demonstrate practice impact with observable indicators earlier, rather than only at the end of the pathway to impact.

The 3U framework addresses the question of "how to demonstrate impact" by clarifying that there are three forms of impact and emphasizing use. To determine the appropriate indicators, an initial scoping can be done by considering whether the research outputs are usable, in-use, or useful. For example, the impact of usable research outputs can be demonstrated in terms of the attention generated among potential users, while the impact of useful research outputs can be demonstrated with evidence of improved effectiveness. Specification of context-relevant indicators can be achieved by accounting for the users' perspective in understanding how research outputs generate benefits.

How to manage research endeavors to make a visible impact? The 3U framework suggests an incremental approach to make research outputs usable, in-use, and useful, thereby benefiting users cumulatively. All three forms of impact can be demonstrated using observable indicators and this shortens the time lag between research and visible impact. A checklist embodying the framework has been provided to aid researchers seeking to demonstrate impact. The 3U framework is descriptive as well as prescriptive. Other than providing a schema for researchers to articulate their impact as it accumulates, it also helps to determine the necessary actions for increasing impact by going beyond offering affordances to improve users' efficiency and effectiveness. This forward-tracking approach is more deliberate and makes the resultant impact more traceable and attributable than the backward tracking approach in which observable impact is analyzed to identify contributing research. The 3U framework can also be applied iteratively to increase impact. When research outputs are less usable, in-use, or useful than expected, the feedback gathered can inform the refinement of research design or development of new, more relevant research questions to produce more impactful research outputs. Such iterations of co-skilling and co-creation ensure that both researchers and users benefit from the endeavor.

By focusing on the notion of use, the 3U framework connects the perspectives of researchers and practitioners to bridge the research-practice gap. To make research outputs usable, researchers must stand in the shoes of potential users to understand their needs. As research outputs are put in use, researchers and users need to communicate and improve user interface. To evaluate usefulness, both parties must agree on the appropriate measures and undertake to ensure data access and rigorous analysis. Both researchers and potential beneficiaries have an active role in driving the realization of impact and share the responsibility.

References

Agarwal, R., and Lucas, H.C. "The Information Systems Identity Crisis: Focusing on High-Visibility and High-Impact Research," *MIS Quarterly* (29:3), 2005, pp. 381-398.

Association to Advance Collegiate Schools of Business "Final Report of the AACSB International Impact of Research Task Force," 2012.

Australian Research Council "EI 2018 Submission Guidelines," 2018a.

Australian Research Council "Engagement and Impact (EI) 2018 Assessment Handbook," 2018b.

Benbasat, I., and Zmud, R.W. "Empirical Research in Information Systems: The Practice of Relevance," *MIS Quarterly* (23:1), 1999, pp. 3-16.

Beyer, J.M. "Research Utilization: Bridging a Cultural Gap between Communities," *Journal of Management Inquiry* (6:1), 1997, pp. 17-22.

Bichler, M., Heinzl, A., and Winter, R. "Practice Impact of IS Research," *Business & Information Systems Engineering* (57:2), 2015, pp. 87-89.

Bornmann, L. "What is societal impact of research and how can it be assessed? A literature survey," *Journal of the American Society for Information Science and Technology* (64:2), 2013, pp. 217-233.

Bornmann, L., and Haunschild, R. "Alternative article-level metrics: The use of alternative metrics in research evaluation," *EMBO reports* (19:12), 2018, p. e47260.

Bornmann, L., Haunschild, R., and Adams, J. "Do altmetrics assess societal impact in the same way as case studies? An empirical analysis testing the convergent validity of altmetrics based on data from the UK Research Excellence Framework (REF)," *arXiv preprint arXiv:1807.03977*), 2018.

Burget, M., Bardone, E., and Pedaste, M. "Definitions and conceptual dimensions of responsible research and innovation: a literature review," *Science and engineering ethics* (23:1), 2017, pp. 1-19.

Davison, R.M., and Bjørn-Andersen, N. "Do we care about the Societal Impact of our research?," *Information Systems Journal* (forthcoming), 2019.

Galletta, D.F., Bjørn-Andersen, N., Leidner, D.E., Markus, M.L., McLean, E.R., Straub, D., and Wetherbe, J. "If Practice Makes Perfect, Where do we Stand?," *Communications of the Association for Information Systems* (45:1), 2019, p. 3.

Given, L.M., Kelly, W., and Willson, R. "Bracing for impact: The role of information science in supporting societal research impact," *Proceedings of the 78th ASIS&T Annual Meeting: Information Science with Impact: Research in and for the Community*, American Society for Information Science, 2015, p. 48.

Gooch, D., Vasalou, A., and Benton, L. "Impact in interdisciplinary and cross-sector research: Opportunities and challenges," *Journal of the Association for Information Science and Technology* (68:2), 2017, pp. 378-391.

Grant, J. "The nature, scale and beneficiaries of research impact: An initial analysis of Research Excellence Framework (REF) 2014 impact case studies," King's College London and Digital Science, 2015.

Guba, E.G., and Lincoln, Y.S. "Competing paradigms in qualitative research," *Handbook of qualitative research* (2:163-194), 1994, p. 105.

Italian National Agency for the Evaluation of the University and Research Systems "Third Mission and Societal Impact of Universities and Research Institutes," 2015.

Joly, P.-B., Gaunand, A., Colinet, L., Larédo, P., Lemarié, S., and Matt, M. "ASIRPA: a comprehensive theory-based approach to assessing the societal impacts of a research organization," *Research Evaluation* (24:4), 2015, pp. 440-453.

Lee, J.K. "Invited Commentary—Reflections on ICT-enabled Bright Society Research," *Information Systems Research* (27:1), 2016, pp. 1-5.

McNie, E.C., Parris, A., and Sarewitz, D. "Improving the public value of science: A typology to inform discussion, design and implementation of research," *Research Policy* (45:4), 2016, pp. 884-895.

Moeini, M., Rahrovani, Y., and Chan, Y.E. "A review of the practical relevance of IS strategy scholarly research," *The Journal of Strategic Information Systems*), 2019.

Myers, M.D., and Klein, H.K. "A set of principles for conducting critical research in information systems," *MIS quarterly* (35:1), 2011.

Niederman, F., Crowston, K., Koch, H., Krcmar, H., Powell, P., and Swanson, E.B. "Assessing IS Research Impact," *Communications of the Association for Information Systems* (36), 2015.

Nunamaker, J.F., Briggs, R.O., Derrick, D.C., and Schwabe, G. "The Last Research Mile: Achieving Both Rigor and Relevance in Information Systems Research," *Journal of Management Information Systems* (32:3), 2015, pp. 10-47.

Nunamaker, J.F., Twyman, N.W., Giboney, J.S., and Briggs, R.O. "CREATING HIGH-VALUE REAL-WORLD IMPACT THROUGH SYSTEMATIC PROGRAMS OF RESEARCH," *MIS Quarterly* (41:2), 2017, pp. 335-351.

Ozanne, J.L., Davis, B., Murray, J.B., Grier, S., Benmecheddal, A., Downey, H., Ekpo, A.E., Garnier, M., Hietanen, J., and Gall-Ely, M.L. "Assessing the societal impact of research: The relational engagement approach," *Journal of Public Policy & Marketing* (36:1), 2017, pp. 1-14.

Penfield, T., Baker, M.J., Scoble, R., and Wykes, M.C. "Assessment, evaluations, and definitions of research impact: A review," *Research Evaluation* (23:1), 2014, pp. 21-32.

Research Excellence Framework "Panel criteria and working methods," 2012.

Research Excellence Framework "Panel criteria and working methods (2019/02)," 2019.

Robey, D., and Markus, M.L. "Beyond rigor and relevance: producing consumable research about information systems," *Information Resources Management Journal (IRMJ)* (11:1), 1998, pp. 7-16.

Rosemann, M., and Vessey, I. "TOWARD IMPROVING THE RELEVANCE OF INFORMATION SYSTEMS RESEARCH TO PRACTICE: THE ROLE OF APPLICABILITY CHECKS," *MIS Quarterly* (32:1), 2008, pp. 1-22.

Royal Netherlands Academy of Arts and Sciences "STANDARD EVALUATION PROTOCOL 2009-2015," 2009.

Strauss, A., and Corbin, J.M. *Grounded theory in practice*, Sage, 1997.

Swanson, E.B. "A Simple Research Impacts Model Applied to the Information Systems Field," *Communications of the Association for Information Systems* (35:1), 2014, p. 16.

United Kingdom Research and Innovation "Guidance on submissions (2019/01),"
    2019.

Vertigo Ventures and Digital Science "Collecting Research Impact Evidence," 2016.

Wiener, M., Saunders, C., Chatterjee, S., Dennis, A.R., Gregor, S., Mähring, M., and
    Mertens, P. "Information Systems Research: Making an Impact in a Publish-
    or-Perish World," *Communications of the Association for Information
    Systems* (43:1), 2018, p. 26.

Appendix

Table 4. Definition/Description of Impact in National Impact Evaluations

Study (in chronological order)	Definition/Description (verbatim)	What does impact mean?	Impact on who?	How to generate impact?	How to measure impact?
Royal Netherlands Academy of Arts and Sciences (2009)	When assessing research activities in terms of societal relevance, evaluators are asked to consider one or more of the following three aspects: • Societal quality of the work. This aspect refers primarily to the policy and efforts of the institute and/or research groups to interact in a productive way with stakeholders in society who are interested in input from scientific research. It may also refer to the contribution of research to important issues and debates in society. • Societal impact of the work. This aspect refers to how research affects specific stakeholders or specific procedures in society (for example protocols, laws and regulations, curricula). This can be measured, for example, via charting behavioural changes of actors or institutions. • Valorisation of the work. This aspect refers to the activities aimed at making research results available and suitable for application in products, processes and services. This includes activities regarding the availability of results and the interaction with public and private organisations, as well as direct contributions such as commercial or non-profit use of research results and expertise.	"how research affects specific stakeholders or specific procedures in society"	"actors or institutions"	• "interact in a productive way with stakeholders" • "contribution of research to important issues and debates in society" • "making research results available and suitable for application"	"can be measured, for example, via charting behavioural changes"
Research	Impact is defined as an effect on, or change or benefit to the economy,	"effect on, or	"economy,		

Table 4. Definition/Description of Impact in National Impact Evaluations					
Study (in chronological order)	**Definition/Description** (verbatim)	**What does impact mean?**	**Impact on who?**	**How to generate impact?**	**How to measure impact?**
Excellence Framework (2012)	society, culture, public policy or services, health, the environment or quality of life, beyond academia.	change or benefit"	society, culture, public policy or services, health, the environment or quality of life"		
Italian National Agency for the Evaluation of the University and Research Systems (2015)	Third Mission and societal impact…has been defined as the openness of the university towards the socio-economic context through the valorisation and transfer of knowledge. A set of indicators were identified related not only to technology transfer (third-party research, patent activity, incubators, spin-off companies, consortia), but also to management of cultural goods.	"openness … towards the socio-economic context"		"valorisation and transfer of knowledge"	"indicators… related to technology transfer…also to management of cultural goods"
Australian Research Council (2018b)	Research impact is the contribution that research makes to the economy, society, environment or culture, beyond the contribution to academic research.	"contribution that research makes"	"economy, society, environment or culture"		

Table 5. Definition/Description of Impact in IS Publications					
Study (in chronological order)	**Definition/Description** (verbatim)	**What does impact mean?**	**Impact on who?**	**How to generate impact?**	**How to measure impact?**

Agarwal and Lucas (2005)	• "The technology we study has had a profound <u>impact on individuals, organizations, industries, and economies</u>" (p. 391)
	• "What is the <u>bottom line</u> from the impact of information technology?
	   o It dramatically alters cost structures and provides new opportunities for revenue
	   o It provides new levels of customer service and convenience
	   o It compels organizations to continually reassess and realign their strategies in response to changes in technology
	   o It creates new industries and innovative forms of business, which generate positive economic activity
	   o It enriches people's lives. From a welfare standpoint, people who have access to this technology are better off" (p. 393)
		"bottom line"	"individuals, organizations, industries, and economies"		• "cost…and…revenue"
					• "customer service and convenience"
					• "new industries and…forms of business"
					• "people's… welfare"

Swanson (2014)	"…two forms of impact: (1) those that occur through <u>direct engagement</u> of academic practice with professional practice, and (2) those that occur through <u>diffusion of practices</u>, both academic and professional, in their respective institutional fields" (p. 307)			• "direct engagement" • "diffusion of practices"	

Table 5. Definition/Description of Impact in IS Publications					
Study (in chronological order)	**Definition/Description** (verbatim)	**What does impact mean?**	**Impact on who?**	**How to generate impact?**	**How to measure impact?**
Bichler et al. (2015)	"While people tend to agree on the importance of IS research impact, there is less of an agreement about how to define such an impact. Indicators include patents, spin-offs, tools and methods developed for companies and other organizations, research funding from industry collaborations, public media citations, consulting reports, invitations to serve as experts on policy questions and government consultation, publications in practitioner journals, and many more" (p. 87)				"patents, spin-offs, tools and methods…research funding…media citations, consulting reports, invitations to serve as experts on policy questions and government consultation, publications in practitioner journals"
Niederman et al. (2015)	"We define research impact as conducting research that makes a difference to individuals, businesses, industries, and societies" (p. 127)	"make a difference"	"individuals, businesses, industries, and societies"		

Table 5. Definition/Description of Impact in IS Publications					
Study (in chronological order)	**Definition/Description** (verbatim)	**What does impact mean?**	**Impact on who?**	**How to generate impact?**	**How to measure impact?**
Nunamaker et al. (2015)	"The impact of the research is maximized as one traverses the last research mile…An interesting idea for a new solution will contribute very little to scholarly knowledge and will make little impact on society until someone takes it through the last research mile…Proof-of-concept technologies are impoverished compared to the proof-of-use systems" (p. 40)		"society"	"traverses the last research mile"	
Lee (2016)	"It would be useful for the IS community to emphasize the impact of IT strategy on society, and vice versa. These research topics can be broadly labeled Macro Information Society (McIS) in contrast to Management Information Systems (MIS) for business. The research questions addressed by McIS should deal with how ICT-based business can change society and how policy about ICT influences the society and business" (p. 2)	"change…and…influences"	"society and business"	Choice of research questions	
Nunamaker et al. (2017)	"Realized impact exists when solutions created by scholarship garner self-sustaining and growing communities-of-use in the field" (p. 339)		"communities-of-use in the field"		

Table 5. Definition/Description of Impact in IS Publications					
Study (in chronological order)	**Definition/Description** (verbatim)	**What does impact mean?**	**Impact on who?**	**How to generate impact?**	**How to measure impact?**
Wiener et al. (2018)	"…assessing impact requires a multidimensional view…point to the importance of considering different <u>stakeholder</u> groups…that includes academic, industry/practice, and society metrics…impactful IS research requires a clear <u>link to real-world problems</u> with a particular focus on the 'grand challenges' of our time… one needs to take on a more active role and serve as 'change agents'" (p. 475)	"multidimensional"	"different stakeholder groups"	• "link to real-world problems" • "more active role and serve as 'change agents'"	"academic, industry /practice, and society metrics"

Table 6. Indicators for Usable Research Outputs in Existing Impact Assessment Programmes		
Focus of Indicators	Research Excellence Framework (2019)	Australian Research Council (2018a)
Effort expended on translation and dissemination	• Publication…figures both in the UK and overseas, …broadcasting data and other forms of media. • Documented evidence of increased social inclusion (e.g., participation figures) • Information about the number and profile of people engaged and types of audience • Evidence of secondary reach, for example from follow-up activity or media coverage • Consultancies to public or other bodies that utilize research expertise	• Established networks and relationships with research users • Outreach activities (public lectures, policy engagements, media engagements, community events) • Contributions/submissions to public enquiries on industry-research related issues • Public lectures, seminars, open days, school visits • Presentations to practitioner communities • Connections to cultural institutions, seminars/ workshops, internships and engagement with the public • Consultations with/advice to community groups, professional/practice

		organisations, government bodies
Attention generated	• Audience or attendance figures (including demographic data where relevant), ...download figures, or database and website hits over a sustained period • Evaluative reviews in the media • Qualitative feedback from participants or attendees at research event • Evidence of public debate in the media or other for being influenced by the research • Quantitative indicators or statistics on the numbers of attendees or participants at a research event, or website analytics for online briefings • Public debate in the media	• Philanthropy linked to research support and in-kind support • Book sales • Metrics which capture social media activity • Event participation statistics (public lectures, cultural events, exhibitions, etc.) • Media coverage of exhibitions and new works

Table 7. Indicators for In-Use Research Outputs in Existing Impact Assessment Programmes		
Focus of Indicators	Research Excellence Framework (2019)	Australian Research Council (2018a)
Breadth	None	• Number of different clients with contracts worth greater than a threshold value • Data around performance and the different types of public activities in which researchers generally report their work to the community or use their research capacity to further the work of community organisations
Depth	• Evidence of take-up and use of new or improved products and processes that improve quality of life or animal welfare in any given context, e.g., developing countries	• Number of licences, assignments and options

Table 7. Indicators for In-Use Research Outputs in Existing Impact Assessment Programmes		
Focus of Indicators	Research Excellence Framework (2019)	Australian Research Council (2018a)
	- Licences awarded and brought to market - Commercial adoption of a new technology, process, knowledge or concept - Evidence of use of process/technology - A new product has been recommended for use or adopted - Evidence of adoption of best practice (e.g., by educators or law enforcement personnel) - Literature/web information from practitioners and advisers, including the research findings and how they are applied in practice - Sales of new products, or improvements in existing products, that bring quantifiable environmental benefits - Traceable reference to inclusion of research into government policy papers, legislation and industry guidance - Evidence of increased public uptake of scientific training, through public engagement - Evidence of use of education materials arising from the research - Demonstrable collaborations with industry (including knowledge transfer partnerships, and contracts). - Evidence of influence on a debate in public policy and practice through membership of or distinctive contributions to expert panels and policy committees or advice to government (at local, national or international level) - Formal partnership agreements or research collaboration with major institutions, NGOs and public bodies. - Evidence of engagement with campaign and pressure groups and other civil organisations (including membership and activities of those organisations and campaigns) as a result of research - Evidence of influence to public policy, legislation, regulations or guidelines - Citation in a public discussion, consultation document or judgment - Evidence of citation in policy, regulatory, strategy, practice or other documents	- Expert witness in court cases - Co-authorship of research outputs with research end-users - Co-funding of research outputs with research end-users - Number of contracts for research, consulting, expert witness and testing - Involving users at all stages of the research, including working with user stakeholder and participatory groups - Evidence of significant institutional partnerships—e.g., various global research consortia, OECD, World Bank, World Health Organisation, UN, UNESCO - Memoranda of Understanding (MOU)/ Agreements

Table 7. Indicators for In-Use Research Outputs in Existing Impact Assessment Programmes

Focus of Indicators	Research Excellence Framework (2019)	Australian Research Council (2018a)
	• Direct citations of research in parliamentary publications such as committee reports, evidence submissions, or briefings • Documented evidence of enhanced awareness of health risks and benefits by consumers • Citation by journalists, broadcasters or social media • Citations in campaign literature (e.g., leaflets)	

Table 8. Indicators for Useful Research Outputs in Existing Impact Assessment Programmes*

Focus of Indicators	Research Excellence Framework (2019)
Efficiency	• Evidence of improved cost-effectiveness • Priority shifts in expenditure profiles or quantifiable reallocation of corporate, non-profit or public budgets
Effectiveness	• Traceable impact on particular projects or processes which bring environmental benefits • Business performance measures (e.g., turnover/profits, trends in key technical performance measures underlying economic performance) • Documented case-specific improvements to environment-related issues • Documented change to professional standards, codes of practice, protocols, performance or behaviour • Documented changes in knowledge, capability or behaviours of individuals benefiting from training • Documented evidence of improved working practices and/or level of production • Documented evidence that public understanding has been enhanced through active collaborative involvement in research • Documented shift in public attitude (e.g., to sexual behaviour, or social factors in health) • Evidence of closing identified skills gaps • Evidence of critical impact on particular projects, products and processes confirmed by independent authoritative evidence, which should be financial where possible • Evidence of enhancement of patient/user experience • Evidence of generic environmental impact across a sector, confirmed by independent authoritative evidence

	- Evidence of improved sustainability - Evidence of research leading to avoidance of negative outcomes - Measures of improved inclusion, welfare or equality. - Measures of improved international equality and food security - Measures of improved public services, including, where appropriate, quantitative information; such information may relate, for example, to the quality, accessibility or cost-effectiveness of public services. - Satisfaction measures (e.g., with services). - Traceable reference to impact of research in planning decision outcomes, national or international industry standards or authoritative guidance, government policy papers, legislation and industry guidance - Traceable references by practitioners to research papers that describe their use and the impact of the research
* Australian Research Council (2018a) did not mention any indicators related to usefulness	

Table 9. Application of 3U Framework to Top IS Impact Cases Submitted to REF 2014					
Institution and Impact Score	**Title and Unit of Assessment**	**Overview of Research**	**Usable Research Output**	**In-Use Research Output**	**Useful Research Output**
Goldsmiths' College (3.87)	Is Another Internet Possible? Power Struggles for the Ownership and Control of Cyberspace (Communication, Cultural and Media Studies, Library and Information Management)	Critical research that explores ways in which developments in information and communication technologies, society, culture, and politics collide and collude with one another, from a macro and micro perspective, on the issue of human rights online	• Reports for policy-makers and NGOs • Presentations at cross-sector meetings (e.g., European Dialogue for internet Governance 2013)	The Brazilian government, the Swedish government, the Council of Europe, and NGOs such as European Digital Rights have drawn upon the research outputs to shape and steer debates about human rights in international and national legal and regulatory frameworks	Reframed the debate, and kept the internet governance and ICT for Development agendas accessible to human rights concerns

Table 9. Application of 3U Framework to Top IS Impact Cases Submitted to REF 2014					
Institution and Impact Score	**Title and Unit of Assessment**	**Overview of Research**	**Usable Research Output**	**In-Use Research Output**	**Useful Research Output**
King's College London (3.9)	Freshwater Information Management and Data Sharing to Meet Environmental Standards (Communication, Cultural and Media Studies, Library and Information Management)	Research into standards, vocabularies and infrastructure for data sharing and integration for environmental datasets	• Methods for "treating" heterogeneous collections of data • Means of carrying out semantic integration of research data sets, harmonising data • Methods of visualising, querying, analysing and processing information in an integrated fashion	• Government agencies and non-governmental agencies use the methods for managing environmental quality • Farmers and land managers use the data access to manage agricultural production levels	Improved UK Environment Agency's compliance with the EU's Water Framework Directive, reducing the risk of financial penalties
Newcastle University (3.90)	Improved processes for the development of dependable systems (Computer Science & Informatics)	Developed formal methods for the design of computing systems, that automate processes, manage mathematical complexities and link with existing industrial standards	Methods are embodied in tools, namely VDMTools, Overture, Rodin	• FeliCa Networks, a subsidiary of Sony and NTT DoCoMo, used VDM tools to develop firmware for an IC chip • Systerel, ClearSy, and Siemens were using the Rodin tools in various industrial projects	Reported improvements in defect detection rates of up to a factor of 5 over previous processes and the cost-effectiveness of design processes

Table 9. Application of 3U Framework to Top IS Impact Cases Submitted to REF 2014					
Institution and Impact Score	**Title and Unit of Assessment**	**Overview of Research**	**Usable Research Output**	**In-Use Research Output**	**Useful Research Output**
University of Cambridge (3.87)	Ubisense (Computer Science & Informatics)	Developed principles of "sentient computing", founded on the notion that computers monitoring or controlling anything in the real world need to be able to sense the environment they operate in	• Ubisense Real Time Location System (RTLS) for tracking components, tools and people, identifying inconsistencies and enabling customized manufacturing • Tool Location System (TLS) software	• RTLS was being used by BMW, Airbus, Aston Martin, Daimler, Atlas Copco and the US Army etc. • TLS was incorporated into smart factory systems, car manufacturing process, and military training	Improved production line accuracy and efficiency by up to 10%
University of Cambridge (3.84)	New IT Strategy for UK Government (Business and Management Studies)	Research showing that a radical approach to the business model and supporting architecture within public services, in which government becomes a component trader, will allow the government to take commercial advantage of its unique scale	• Independent report for the Conservative Party • ICT spend controls methodology	• The UK government implemented the strategic changes based on the research • The UK government and OECD adopted the ICT spend controls methodology • The UK government's pocket guidebook for ICT procurement was developed based on the research	The research led to IT policy that resulted in IT cost saving amounting to £400 million in 2012

Table 9. Application of 3U Framework to Top IS Impact Cases Submitted to REF 2014					
Institution and Impact Score	**Title and Unit of Assessment**	**Overview of Research**	**Usable Research Output**	**In-Use Research Output**	**Useful Research Output**
University College London (3.80)	A clinical management service for stroke prevention (Computer Science & Informatics)	Developed an electronic health record (EHR) information architecture (information models, knowledge models, persistence architecture and services) to represent "cradle to grave" information	An EHR repository	The repository was being used by 5 Clinical Commissioning Groups (CCG) across north London and Hertfordshire, covering 2 Hospital Trusts, 30 General Practice delivery sites and 3 Community Pharmacies	Every prevented stroke saves the NHS £16,000 per annum; the estimated saving to each CCG is approximately £500,000 per annum
University College London (3.8)	Human-centred security in government and commercial applications (Computer Science & Informatics)	Developed a design of usable security that works with and for, rather than against, users and their organisations	• The "0 effort, 1 step, 2 factor" authentication mechanism and compliance budget model • Advices to government and companies	• Adoption in public services and businesses • Incorporation in security products	One of the resulted security products protected over 70% of UK online shopping revenue

Table 9. Application of 3U Framework to Top IS Impact Cases Submitted to REF 2014					
Institution and Impact Score	**Title and Unit of Assessment**	**Overview of Research**	**Usable Research Output**	**In-Use Research Output**	**Useful Research Output**
University of Southampton (3.84)	Leading the open data revolution (Computer Science & Informatics)	Developed linked data methods, new ways to standardise how data is presented online	Artifacts developed in a pilot study demonstrating how government and agencies could integrate, share, and use its distributed data	• Public Data Principles were enshrined in the UK Government Open Data White Paper • data.gov.uk was launched in 2010 to serve as the main online access point to thousands of government datasets relating, among others, to crime, health and education • Informed open data initiatives in the USA, EU and G8	Some open datasets served as the basis for successful applications, such as "Fix My Street" and "Who's Lobbying"
University of Strathclyde (3.75)	Improved group negotiation, problem solving, and strategy making in private and public sector organisations (Business and Management Studies)	Research on strategic problem solving, strategy making, and developing effective collaboration	A Group Decision Support System (GDSS) and accompanying methodology that improves group negotiation and the quality of agreements in organisational settings	System and methodology adopted by senior teams in the NHS, DECC, Balfour Beatty, EdF, Land Engineering, Strathclyde Police, and Office for Nuclear Regulation (ONR), Scottish and Southern Energy, among others within and outside the UK	Users noted significant improvement in the effectiveness of collaboration, strategic problem solving and strategy making