

Evolution of Data Creation, Management, Publication, and Curation in the Research Process

by

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Abstract

Sharing research data and scholarship is of national importance due to the increased focus on maximizing return on the government's investment in research programs. Recent policy changes have directly affected the management and accessibility of publically-funded research. On January 18, 2011 the National Science Foundation (NSF) required data management plans to be submitted with all grant proposals. On February 22, 2013, the Office of Science and Technology Policy of the President of the United States extended a similar requirement to all federal agencies with research and development budgets of more than \$100 million. These requirements illustrate the need for further coordination and management of data as scholarship with traditional publications. The Purdue University Libraries and the Joint Transportation Research Program (JTRP) collaborated to develop a comprehensive work flow that links technical report production with the management and publication of associated data. This paper illustrates early initiatives to integrate discrete data publications with traditional scholarly publications through leveraging new and existing repository platforms and services. The authors review government policies, past data sharing practices, early pilot initiatives, and work flow integration between Purdue's data repository, traditional press, and institutional repository. Through the adoption of these work flows, the authors propose best practices for integrating data publishing and dissemination into the research process. The implementation of this model has the potential to assist researchers in meeting the requirements of federal funding agencies, while reducing redundancy, ensuring integrity, expanding accessibility, and increasing return on research investment.

Introduction

Motivation for sharing research data has accelerated in the past few years with funding agency requirements and government policies. In 2010, the National Science Federation (NSF) announced it would require a data management plan (DMP) to be submitted with all grant proposals beginning on January 18, 2011 [1]. The DMP is a supplemental document describing how the researchers will disseminate and share research results, including data. Since then, other funding agencies such as National Institutes of Health (NIH) and Department of Energy (DOE) have issued similar requirements related to research data access and sharing. In 2013, John Holdren, Director of the Office of Science and Technology Policy (OSTP) issued a memo that stated, "Access to digital data sets resulting from federally funded research allows companies to focus resources and efforts on understanding and exploiting discoveries [2]."

However, only a small fraction of the US transportation related research is conducted by agencies such as the NSF. The majority of transportation research is conducted in a decentralized model using State Planning and Research (SPR) Funds, with United States Department of Transportation (USDOT) investing approximately \$190M per year in SPR research [3]. Another \$72.5M is invested annually for their University Transportation Center (UTC) program for fiscal years 2013 and 2014 [4]. In a September 2011 webinar, Federal Highway Administration (FHWA) Administrator Victor Mendez cited the importance for state transportation departments to investigate methods to reduce duplication of research activity and identify ways to collaborate and leverage peer state research [5]. One way research centers can work towards this collaboration is to integrate data sharing processes into the technical report publication process and link the data sets to those technical reports.

Past Practices

The historical lack of data sharing that has prompted interest at a national level is perhaps due to a combination of limited journal page budgets available to authors, relatively small data sets, and lack of long-term data repositories. Furthermore, researchers often devote years to collecting data sets whose value has predominantly been recognized by citations to papers summarizing findings from the data. Perhaps the American Association of State Highway and Transportation Officials (AASHTO) Road Tests of the 1950's illustrate both the effort necessary to collect research data and past practices to widely share information summarizing findings from the research data rather than the raw or processed data itself [6,7,8,9,10].

Government investment in research and technological advances over the past few decades have resulted in the generation of research data sets that are in many cases an order of magnitude larger than collected in the past. The so-called data deluge has presented a daunting challenge for management, access, and preservation of research data produced with public funding.

Integrating Data and Research Literature

Linking data to the research literature fosters reproducibility [11], and reduces research redundancy, with an aim to decrease investment in duplicative research, both nationally and globally. Research data and literature need to be thought of as two integrated pieces. Data should be linked to the scholarly publications to meet the needs of future researchers.

"Data are the infrastructure of science. Sound data are critical as they form the basis for good scientific decisions, wise management and use of resources, and informed decision-making" [12]. In addition to complying with funder and government requirements, there are many benefits to sharing research data, such as the ability to validate research findings, reducing duplication of research, reducing research

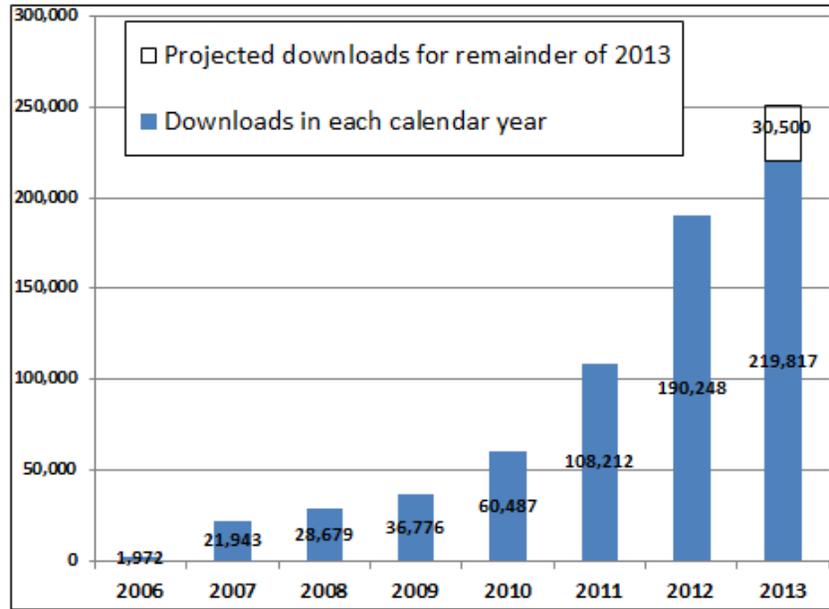
costs by data re-use, and increasing impact through data set citations [13]. A joint report published in 2009 by The National Academy of Sciences, The National Academy of Engineering, and the Institute of Medicine emphasizes the need to develop policies and define work flows for managing and sharing research data for the purposes of ensuring research and data integrity, accessibility, and preservation [14]. Many researchers are willing to share their data, but do not have mechanisms to do so.

Sharing research data has been prevalent in disciplines such as biology and genetics and has been referred to as e-science or e-research. Schroeder [15] states that e-science is “the use of shared computing resources for research.” This can include research data, tools, and other technologies used to promote collaboration. However, dissemination and archiving of technical transportation literature has been historically limited to research papers and grey literature, such as technical reports published through federally funded research grants [16].

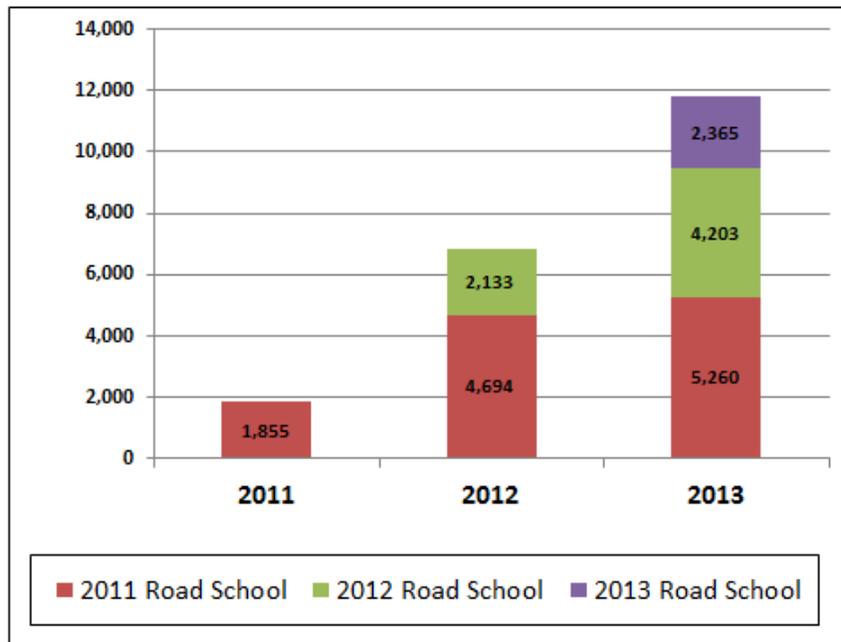
Case Study

The Joint Transportation Research Program (JTRP) is a partnership established in 1936 between the Indiana Department of Transportation (INDOT) and Purdue University that facilitates and funds collaboration with higher education institutions, agencies and industry to implement innovations that result in continuous improvement in the planning, design, construction, operation, management and economic efficiency of the Indiana transportation infrastructure. Since 2006, the Purdue University Libraries (PUL) has been working closely with JTRP authors and administrators to improve production, dissemination, and stewardship of technical reports produced over the last 60 years [16]. This collaboration resulted in the JTRP Technical Reports collection in Purdue e-Pubs [17].

The impact of this collaboration between Purdue Libraries and JTRP can be seen in the COUNTER-compliant usage statistics that show the 1,500 technical reports produced have been downloaded over 668,000 times (Figure 1A) since 2006. In 2012, the reports were downloaded over 190,000 times with a trend of approximately 10% increase per month. It is projected that 2013 downloads will approach 250,000, which is an approximate 30% increase over 2012. Furthermore, Google Analytics has indicated that a considerable number of users accessing the materials were internationally based, with particularly strong representations from India, China, and South Korea. In 2011, this partnership with the Purdue Libraries was expanded to include archiving of presentations from an annual transportation conference called the Purdue Road School attended by over 2200 participants. Downloads have increased year over year of both current presentations and those of past conferences. The download statistics for that material are shown in Figure 1B.



A) JTRP Technical Report Downloads



B) Purdue Road School Presentation Downloads as of November 10, 2013

Figure 1: Purdue e-Pubs Downloads¹

The collaboration by Purdue Libraries and JTRP was further expanded to include the deposit of affiliated data sets, additional reports, and supplemental materials in the Joint Transportation Research Program Collection on e-Pubs [17]. Examples of this expanded collection include the Indiana Mobility Reports, which provide a quantitative evaluation of the performance of the Indiana interstate system [18] [19].

¹ The technical report graph has the projected downloads for 2013. The Road School downloads are as of 11/10/2013. If this paper is published, we will update downloads through 12/31/2013.

The Purdue e-Pubs collection contains data sets that were cases of ad hoc responses to JTRP data needs. For example:

- A traditional raw numerical data set, Data Set for Investigating Computational Efficiency of Alternative Arterial Offset Optimization Algorithms [20], was published through Purdue e-Pubs after the technical paper was published due to requests by a colleague at a peer institution inquiring about the availability of data associated with the technical report [21].
- In another case, the data set was published prior to the peer review process, to provide multi-media context [22] to the reviewers and future readers regarding the conditions under which the data set referenced in the technical paper [23] was collected.
- In another situation, a data set was added to Purdue e-Pubs to archive a data set video [24] within the repository which provided the same bibliographic record and metadata indexing record capabilities as the technical report that referenced the data set video [25]. This example demonstrates that the enhanced discoverability of reports on the e-Pubs platform generated interest in access to the relatively old video collected during the research process.

In all of these cases, the data was added to Purdue e-Pubs prior to the formation of the Purdue University Research Repository (PURR) and before PURR's currently implemented collection development policy [26]. These examples demonstrate the need for a data publishing platform to privately share and openly publish research data, the need to create an integrated data and technical report publication workflow, and the need for standardized publication practices. The ability to iterate publications, both data and traditional, allows research to become more open, useful, and collaborative.

Comprehensive Publishing Vision and Supporting Organizational Structure

As the needs of researchers evolve, academic libraries are choosing to become publishers to meet those changing needs. Several recent changes to public policy regarding publicly funded research have also illustrated the need to enhance the visibility and dissemination of both the published research findings and the research data. The creation of comprehensive publishing work flows is needed, when both the data and publications are being created in conjunction with one another, to prevent the final products becoming disjointed because of a lack of cross connectivity and visibility. The comprehensive work flow in essence is the attempt to fill the missing gaps in the research dissemination process. In a 2012 Institute for Museum and Library Services (IMLS) final report by Purdue University, Georgia Technical University, and the University of Utah, approximately 55% of survey respondents from of all sizes of academic libraries were either implementing or currently developing library publishing services. This included 75% of the membership of the Association of Research Libraries, representing the largest research libraries [27].

Newton et al. reported that by leveraging the publishing and repository services resources and expertise of the libraries and press, researchers were able to increase discoverability and add value to the reports through the press' manageable review and production process and through the use of the Digital Commons repository software's publishing and manuscript management capabilities [16]. This provided researchers an opportunity to modernize the report production process. The press and library partners were also able to add to this value by assigning CrossRef Digital Object Identifiers (DOIs) and increasing the discoverability and visibility of the reports. This has resulted in broader dissemination of the JTRP scholarly research and provided an early example of the benefits of integrating library and publishing colleagues into research center activities.

Since the publishing of the Newton et al. paper, the Purdue Libraries has sought to increase its publishing capabilities in providing a much more collaborative service model to meet the needs of campus partners. In March of 2012, the Purdue University Press became more strategically aligned with the Purdue Libraries, creating a stronger partnership for campus publishing activities through formation of the new Libraries Publishing Division. The Purdue Libraries Publishing Division is comprised of two distinct yet parallel units: the Purdue University Press and Scholarly Publishing Services, which is where Purdue e-Pubs is organizationally contained since its formation in 2006. The mission of the division is to maximize access to scholarly publications in financially sustainable open models for the benefit of users across the State, nation, and world [28].

Through this partnership, the Libraries now offers a range of publishing services that are beneficial to the university and our stakeholders. These publishing services improve the impact and extend the reach of Purdue research and scholarship through the development of books, pre-and post-print collections, conference proceedings, technical report publications, and other unique publishing opportunities so that the Libraries can further engage with its stakeholders like JTRP [28].

Purdue e-Pubs

Since 2010, Purdue e-Pubs has been both the hosting repository and publishing platform for JTRP technical reports and is built on the Digital Commons repository platform. One of the major advantages of Digital Commons is the ability to provide content creation management of the various stages in the production process through the repository's manuscript management system capabilities [29]. This has allowed for a more holistic production process that mirrors standard processes for journal article production and publication. JTRP funds a production editor who is responsible for the management of both the review process and production of reports through the Purdue e-Pubs repository.

Early Lessons Learned

The ad hoc responses to JTRP data needs noted above illustrate early pilot initiatives to leverage the existing e-Pubs repository to provide open access to data sets. Several important lessons were learned:

1. It was critical to be able to create citations to the data sets so that authors could receive proper attribution.
2. Leveraging the libraries core competency of preservation was important to provide authors with a trusted location with a persistent URL to deposit their data.
3. The "data" would be quite diverse and range from traditional numerical data and accompanying metadata [20], to more sophisticated data sets such as audio [22], video [24] and narrated short movies [30].
4. For the foreseeable future, there would be a need to deposit data associated with legacy reports [25] as well as deposit and mint citations prior to technical papers being distributed for review [22] [23].

The Purdue University Research Repository (PURR)

These early lessons learned and emerging infrastructure needs aligned closely with parallel activities on campus examining the institutional issues associated with data management. Beginning in 2011, the Purdue Libraries, in collaboration with the Office of the Vice President of Research (OVPR) and Information Technology at Purdue (ITaP) began the development of a service and software platform designed to assist Purdue researchers in meeting the data management plan (DMP) requirements of granting agencies. These collaborators combined their expertise to create the Purdue University Research Repository (PURR), a new, designated university core research facility providing a web-based institutional data repository for Purdue faculty, graduate students, and staff [31].

The PURR hub, built using Purdue's HUBzero open-source platform, "support(s) collaborative development and dissemination of scientific models running in an infrastructure that leverages a 'cloud' of computing resources [32]." PURR extends the capabilities of HUBzero by allowing the user and invited collaborators access to a secure, shared data project space and the ability to publish data as scholarship with a Datacite DOI [33]. PURR provides researchers with a set of resources and services, including guides, tutorials, boilerplate text, and subject specialist librarian (SSL) consultation to aid in drafting DMPs for grant proposals which are compliant with funder and federal requirements.

PURR's development and practices are guided by ISO 16363, and are currently seeking certification. This eye on evolving industry standards throughout development and on PURR's data curation ensures data sets are on a track for long-term preservation and management in a trustworthy digital repository [34].

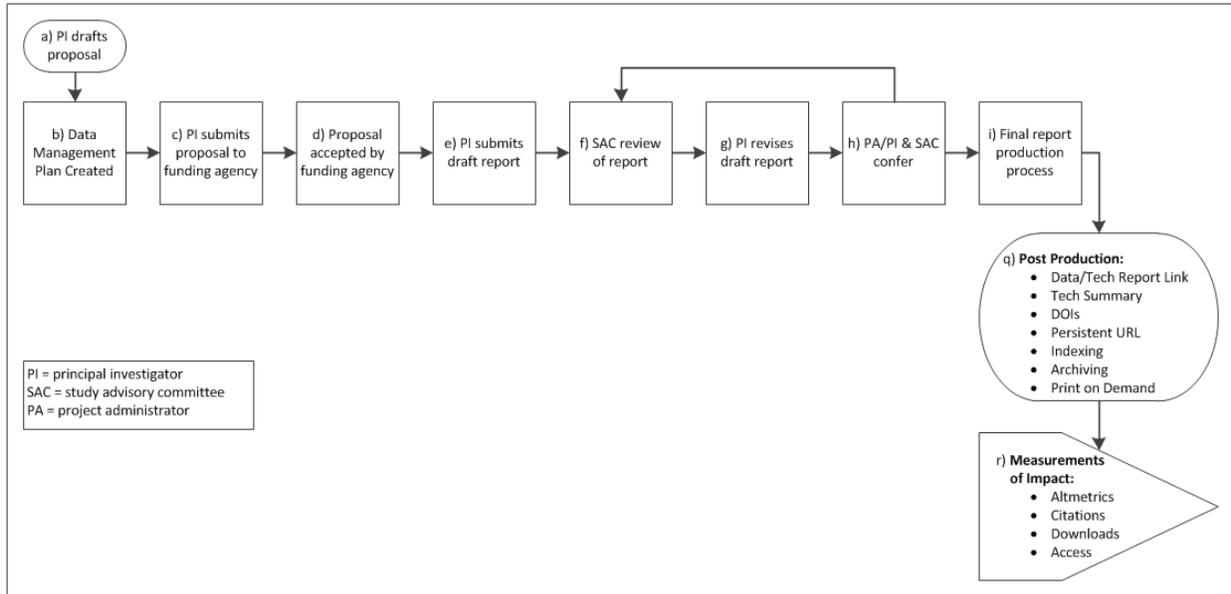
Research Support Work Flow Models

The work flow used for the production and publication of the JTRP technical reports mirrors the production work flow for traditional scholarly journal publications (Figure 2A). When a PI (principal investigator) completes a research project, the process for the production of the technical report begins with the submission of the manuscript draft by the PI (Figure 2A-e). The PI makes any necessary corrections to the report and then provides a revised copy to the PA (project administrator) and BO (business owner) prior to the close-out SAC (Study Advisory Committee) meeting. At the discretion of the PA and BO, additional subject matter experts on the SAC may be consulted as well. The PI schedules a close-out SAC meeting, at which the final report is presented to the SAC. This process is repeated as necessary as these individuals introduce necessary corrections and revisions to the reports from the report reviewers (Figure 2A-f, g, h). The PI submits the final report and technical summary to the repository after it is approved by the SAC.

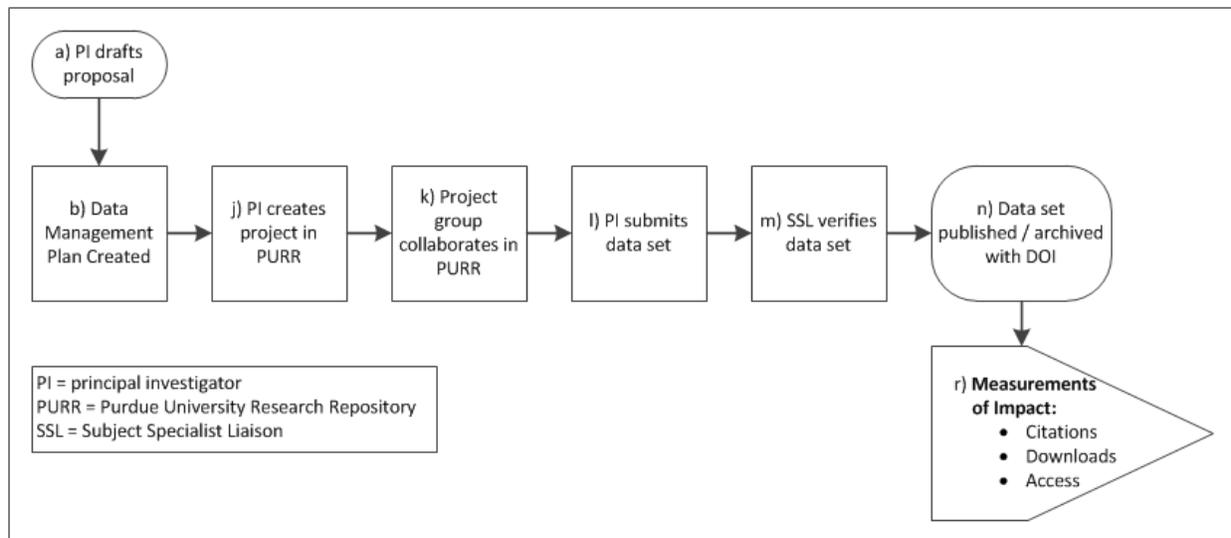
Once the report and technical summary has been submitted, the production editor forwards these materials to JTRP and INDOT for approval of final publication. The production editor assigns bibliographic metadata and a DOI after the report has been approved for publication. Included in the bibliographic metadata is the author's email addresses so that they will receive their monthly download reports directly from the repository software. After the report has been approved for publication, the Production Editor manages the report production process, which includes the creation and verification of the DOI, light copyediting, and typesetting of the report and technical summary. Once the report and technical summary have been prepared for publication, they are made available directly through the repository. The report then enters the post-production stage, which includes registration of the DOI, assignment of the persistent repository URL, electronic indexing, archiving, and creation of the report's print on demand version (Figure 2A-q, Figure 6A-2).

The JTRP PURR work flow model (Figure 2B) operates independently of the JTRP Technical Report work flow. Using the PURR platform, a Purdue PI is able to create a PURR project (Figure 2B-j). This occurs after the PI has submitted a proposal and drafted a data management plan. The project enables the PI to upload, share, and manage data with invited collaborators from Purdue and external organizations (Figure 2B-k). The PI then selects and describes files from the project and submits the packaged data set for publication. The submitted data set package is reviewed by the SSL from the PI's discipline and, once approved, it is published with a DOI, made accessible on the PURR website and in the PUL catalog, and maintained for 10 years (Figure 2B-n). During this 10-year period, data sets are provided as Open Data and are searchable in and linked to from the Purdue University Libraries'

Catalogue. After the end of the initial project commitment, data sets are reviewed by a subject specialist liaison and a digital archivist to determine if the data set meets the PURR Digital Preservation Policy requirements to be maintained permanently [35]. PURR measures each data set’s impact by providing publically the total number of downloads and the total number of users who have downloaded the data set.



A) JTRP e-Pubs Technical Reports



B) JTRP PURR Data Sets

Figure 2: Discrete JTRP Work Flow Models

The comprehensive publication work flow combines the Purdue e-Pubs and PURR work flows into one. The work flows operate in parallel with points of communication, specifically when the data management plan is created, the DOI is minted with PURR, and at the point of the final metadata creation (Figure 3-b&j,g&o,i&p). PURR and Purdue e-Pubs each issue DOIs for the discrete resources

contained in their respective repositories. These DOIs are used to provide links to and from the metadata record of the respective resource(s) to the related resource(s) in the other repository. The comprehensive work flow also allows for more robust measurements of impact, measuring each publication separately, and then as a combined publication.

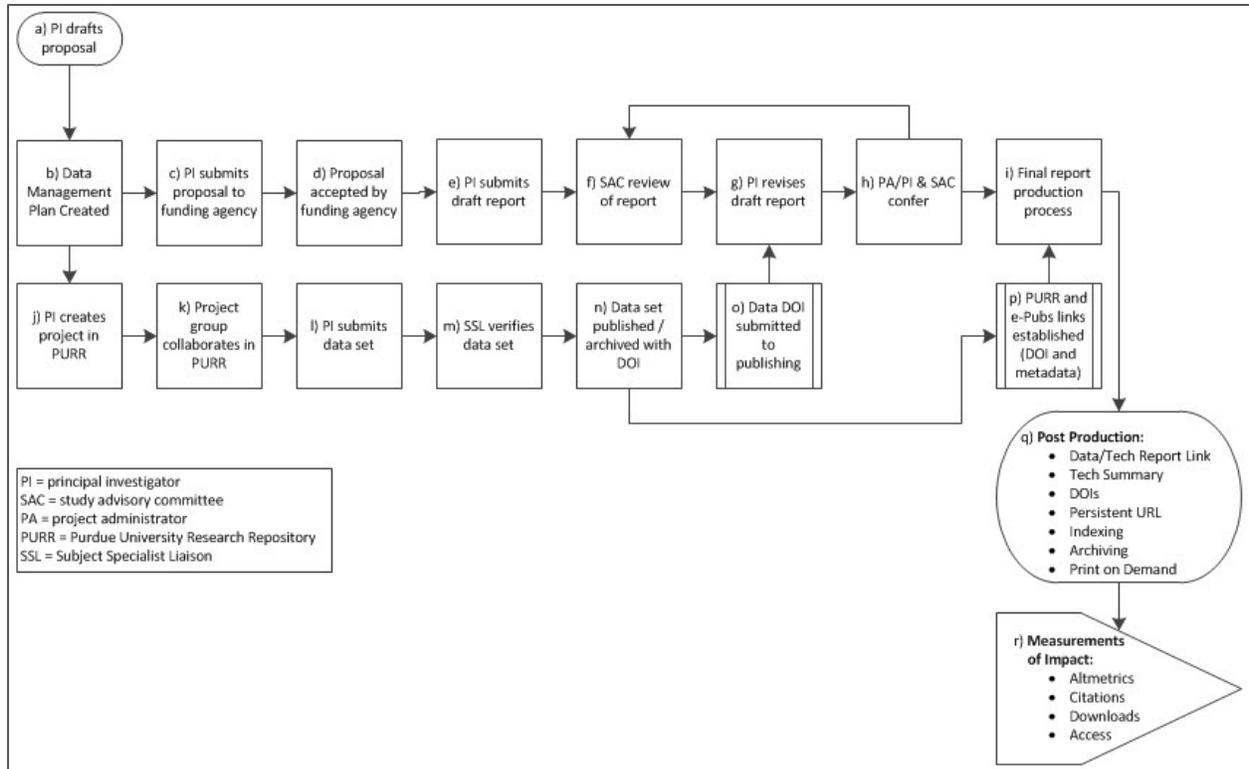


Figure 3: JTRP Comprehensive Publication Work Flow Model

Model for Linking Technical Reports and Data Sets Moving Forward

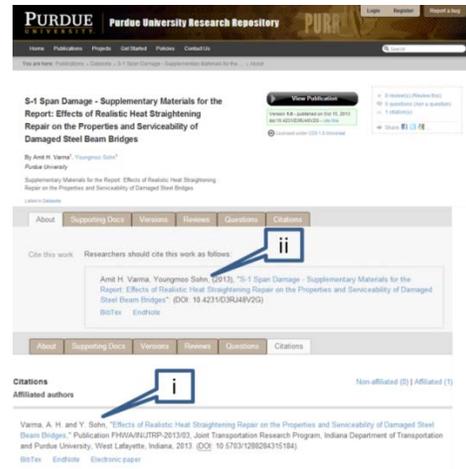
The previous section describes processes for integration and coordination of publishing process for both data and technical reports (Figure 3). The data publication (Figure 3p) and subsequent cross referencing with published technical reports (Figure 3i) is a crucial step. The efficacy of the comprehensive work flow has been demonstrated by Dr. Amit H. Varma and Dr. Youngmoo Sohn. In consultation with the Purdue University Press and Libraries, they utilized the comprehensive workflow to interlink and publish their technical report [40] and ten research videos dataset publications [41,42,43,44,45,46,47,48,49,50]. Figure 4 and Figure 5 illustrate the output of those processes.

- Figure 4A shows a representative web page with metadata and citations for the technical report depicted in Figure 5A.
- Figure 4B shows the metadata and citations for the data set shown in Figure 5B and Figure 5C.

Of particular note is that the technical report web landing page (Figure 4A) contains two citations, a citation to the technical report (Figure 4A-i) and a citation that cross references the data set (Figure 4A-ii). The data set web landing page (Figure 4B) contains citations to both the data set (Figure 4B-ii) and a cross reference citation to the technical report (Figure 4B-i).

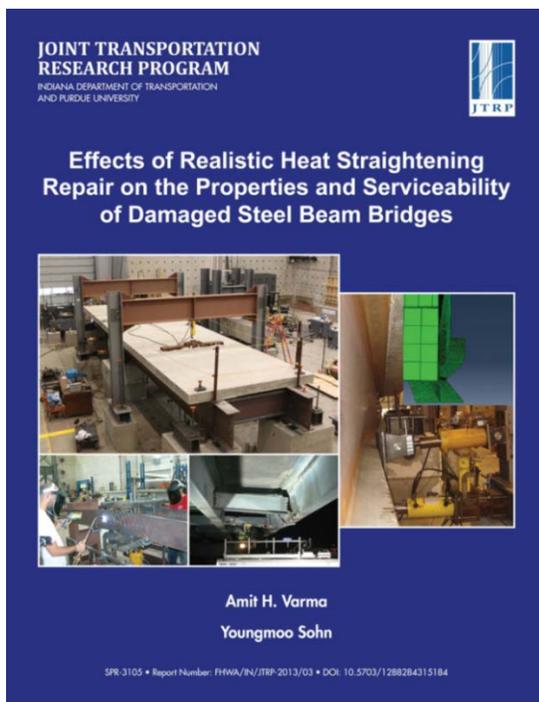


A) Technical Report Web page



B) Data Set Web page

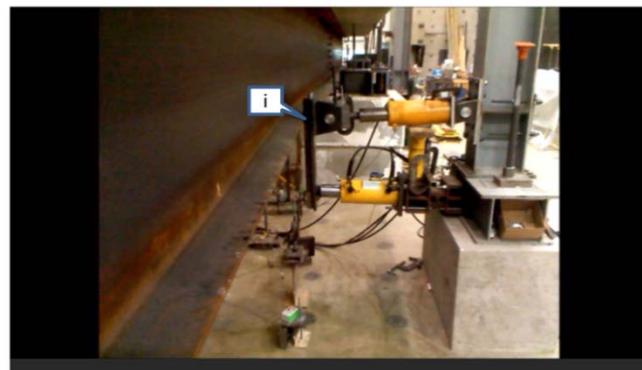
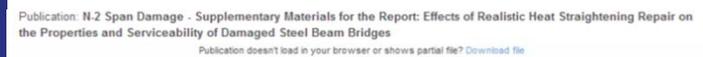
Figure 4: Example Technical Report Web and Data Sets Web Page Portal



A) Technical Report
DOI: 10.5703/1288284315184



B) Image of video prior to actuator deflection of beam
DOI: 10.4231/D38G8FH7Z



C) Image of video during actuator deflection of beam
DOI: 10.4231/D38G8FH7Z

Figure 5: Example Content

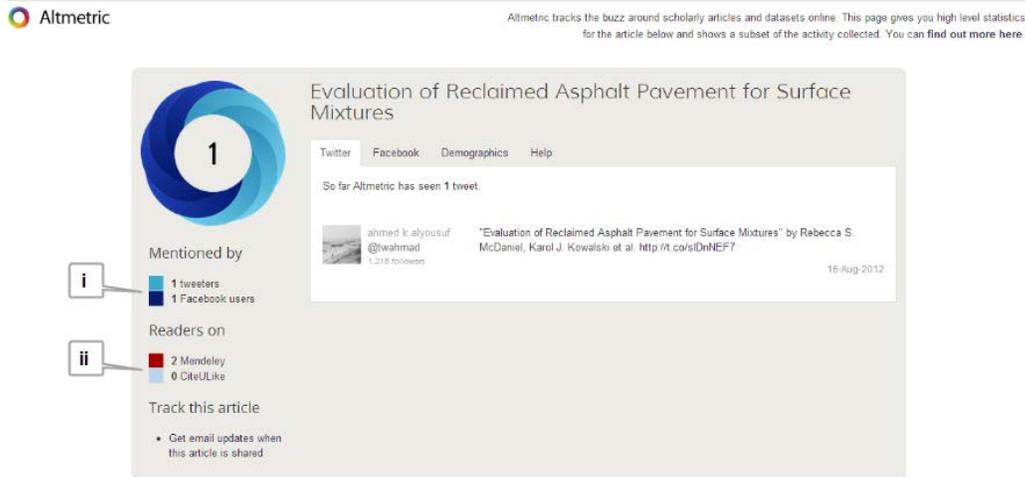
Linking this report to the visual data provides us with an example of how data can be harnessed and rendered reusable for a larger community of scholars. Assigning DOIs to the data and interlinking it with finalized technical report provides a greater return on funder investment and demonstrates accessibility meeting Federal mandate directives.

Measurements of Impact

Purdue e-Pubs and PURR provide statistics and measurement capabilities so that the quantitative and qualitative measurements of impact can be determined (Figure 3-r). Purdue e-Pubs is able to provide authors, users, and collection administrators several ways to measure access, usage, and impact of their publications. Each month authors receive an automatic email from the repository reporting the COUNTER-compliant download statistics on their items, while administrators also receive an email reporting downloads for the series and collections under their purview (Figure 6A-i). Access statistics can be provided to administrators via Google Analytics monitoring. The repository is also monitoring publications via altmetrics, statistics and social web metrics [36], through the implementation of the Altmetric [37] (Figure 6A-iii) plug-in tool, as well as the forthcoming implementation of the ImpactStory [38] plug-in tool. PURR currently tracks and provides a public listing of total data sets downloads and the total number of downloads by unique users for each individual data set. Future tools to assist researchers to measure the impact of their published data includes a monthly email report detailing monthly and total data set downloads and monthly and total unique visitors count.



A) Altmeter API Button



B) Link to Altmeter Page

Figure 6: Implementation of Altmeter for JTRP Technical Report SPR-3018 [39]

Moving Forward

Our early work to incorporate data as scholarship into the technical report publication process has resulted in several best practices:

- **Linked workflows:** Linking publishing and data work flows allows for the researcher(s), repository manager(s), editor(s), and SSL(s) to coordinate resources and anticipate needs at each step of the process. Without a comprehensive publication work flow, the process can become cumbersome to the researchers and important information can be lost.

- **Early interaction with the data repository:** The authors' experiences have led to the conclusion that early interaction with the data repository was paramount to our success. The sooner an investigator begins working with the PURR services and support group the higher the likelihood for good data management principles and practices to be employed. In the case of JTRP, standardizing the integration of the PURR service and platform into the comprehensive publication work flow (Figure 3) will increase the ease of citation of the data and increase the impact of both the published data and the traditional scholarship.
- **Traditional publication attributes:** Increasing the visibility and discoverability of both the data publications and the traditional technical report publication is accomplished by incorporating standard publication attributes, allowing each publication to appear as a traditional publication. These attributes include an identifiable bibliographic record of metadata, a standard and recognizable citation (Figure 6A-iv), secure URL, DOI, and any funding grant information required by the granting agency. Without these publication attributes, the ability to measure and assess the impact through qualitative and quantitative means may be lost, which can diminish the discoverability and visibility of both publications. Further visibility of the publication and increased access to taxpayer funded research can be achieved by making these publications openly available. This allows the sponsoring organizations to be compliant with funder requirements, including the recent requirement from the Office of Science and Technology Policy of the President of the United States.
- **Usage and access metrics:** Through the use of the recognized publication attributes, the research usage and access metrics can be monitored and statistically evaluated through both quantitative and qualitative measurements. The research's impact can be widely monitored and can provide a richer story by having a balance of quantitative and qualitative data. These metrics may include repository download and access data, Google Analytics metrics, Google Scholar data, and altmetric data. In several recent studies, altmetrics have been found to be early indicators that can predict later citations and research impact for Open Access (OA) content [51-52]. A mixture of impact metrics (Figure 3r, Figure 6B-i&ii) allows both researchers and stakeholders to monitor how research is being recognized and the effect of making these materials openly available. By implementing altmetrics directly, users, authors, and stakeholders can monitor the communication of the publications in social media and other alternative metric venues in the repositories. By conducting these multiple measurement and assessment activities, the repositories can provide a diverse set of mechanisms to communicate the impact of the materials in the repository that may have been otherwise overlooked, which causes delay in the period when impact can be demonstrated.

Libraries provide transportation researchers, research centers, and DOTs with the platforms and the consultative services that enable researchers to more fully tell the story of their research. The comprehensive workflow presented in this paper broadens the conception of what transportation scholarship is and can be, assists in achieving compliance with funder and federal mandates, and helps define best practices in Library Science.

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