
PERMA: SCOPING AND ADDRESSING THE PROBLEM OF LINK AND REFERENCE ROT IN LEGAL CITATIONS

*Jonathan Zittrain, Kendra Albert, and Lawrence Lessig**

INTRODUCTION

Works of scholarship have long cited primary sources or academic works to provide sources for facts, to incorporate previous scholarship, and to bolster arguments. The ideal citation connects an interested reader to what the author references, making it easy to track down, verify, and learn more from the indicated sources.

In principle, as cited sources move to the Web, this linking should become easier. Rather than requiring a reader to travel to a library to follow the sources cited by an author, the reader should be able to retrieve the cited material immediately with a single click.

But again, only in principle. The link, a URL, points to a resource hosted by a third party. That resource will only survive so as long as the third party preserves it. And as websites evolve, not all third parties will have a sufficient interest in preserving the links that provide backwards compatibility to those who relied upon those links. The author of the cited source may decide the argument in the source was mistaken and take it down. The website owner may decide to abandon one mode of organizing material for another. Or the organization providing the source material may change its views and “update” the original source to reflect its evolving views. In each case, the citing paper is vulnerable to footnotes that no longer support its claims. This vulnerability threatens the integrity of the resulting scholarship.

This problem does not exist for printed sources, or at least not in the same way. Print sources can be kept indefinitely by libraries or archives, assuming space and other determinations allow. The ability to update those original print sources is, for these purposes, happily difficult. Tracking down every original copy of an edition of a printed *New York Times* and changing a story on page A4 is the stuff of Or-

* Jonathan Zittrain is Professor of Law at Harvard Law School and the Kennedy School of Government, and Professor of Computer Science at the Harvard School of Engineering and Applied Sciences. Kendra Albert is a JD candidate at Harvard Law School. Lawrence Lessig is the Roy L. Furman Professor of Law and Leadership at Harvard Law School, and Director of the Edmond J. Safra Center for Ethics at Harvard University. We thank research assistants Nicholas Fazio, Benjamin Sobel, Leonid Grinberg and Shailin Thomas for their work, Constantine Boussalis for statistical assistance, and Raizel Liebler and Martin Klein for their helpful feedback. The authors recognize the efforts of the Harvard Law School Library Innovation Lab, in particular Kim Dulin, Matthew Phillips, Annie Cain, and Jeff Goldenson, in taking perma from idea to reality.

well's imagination, not real-world practicality. But to do the same thing with an online edition is trivial.

As newspapers, government agencies and other non-academic sources move to primarily digital publication, law review articles increasingly reference online materials, sometimes in lieu of, or in addition to, a print source.¹ When online material does not have a formal paper counterpart such as a published book or journal article, there are few repositories that keep copies of the linked material from citations. Instead, linked material remains in the custody of its single host, rather than being distributed among libraries or readers.

Because of this, materials at links frequently (1) become inaccessible or (2) change, a phenomenon known as “link rot” and “reference rot,” respectively. Link rot refers to the URL no longer serving up any content at all. Reference rot, an even larger phenomenon, happens when a link still works but the information referenced by the citation is no longer present, or has changed.²

Building on previous studies of link rot,³ we have reviewed links published within three legal journals — the *Harvard Law Review* (HLR), the *Harvard Journal of Law and Technology* (JOLT) and the *Harvard Human Rights Journal* (HRJ) — as well as the links contained across all published United States Supreme Court opinions. We exploited the unique citation style of law reviews and court opinions, including the extensive cite-checking process, which meant that in almost all cases, we were able to determine whether the original information was present. Thus, our study was able to validate previous findings of link rot in law review and Supreme Court citations, as well

¹ For example, *The Bluebook* style guide for legal citation says: “*The Bluebook* requires the use and citation of traditional printed sources when available, unless there is a digital copy of the source available that is authenticated” THE BLUEBOOK: A UNIFORM SYSTEM OF CITATION R. 18.2, at 165 (Columbia Law Review Ass’n et al. eds., 19th ed. 2010).

² The Hiberlink and Memento project team at Los Alamos National Lab helpfully distinguishes between the two phenomena — a useful distinction that we import. See Robert Sanderson, Mark Phillips, & Herbert Van de Sompel, *Analyzing the Persistence of Referenced Web Resources with Memento*, ARXIV (May 17, 2011, 7:21 PM), <http://arxiv.org/abs/1105.3459>, archived at <http://perma.cc/oees5QbGfp5F>.

³ E.g., Helane E. Davis, *Keeping Validity in Cite: Web Resources Cited in Select Washington Law Reviews, 2001–03*, 98 LAW LIBR. J. 639 (2006); Raizel Liebler & June Liebert, *Something Rotten in the State of Legal Citation: The Life Span of a United States Supreme Court Citation Containing an Internet Link (1996–2010)*, 15 YALE J.L. & TECH. 273 (2013); Mary Rumsey, *Runaway Train: Problems of Permanence, Accessibility, and Stability in the Use of Web Sources in Law Review Citations*, 94 LAW LIBR. J. 27 (2002); Wallace Koehler, *A Longitudinal Study of Web Pages Continued: A Consideration of Document Persistence*, 9 INFORMATION RESEARCH, (Jan. 2004), <http://informationr.net/ir/9-2/paper174.html>, archived at <http://perma.cc/8767-F7NG>; John Markwell & David W. Brooks, “Link Rot” Limits the Usefulness of Web-based Educational Materials in Biochemistry and Molecular Biology, 31 BIOCHEMISTRY & MOLECULAR BIOLOGY EDUC. 69 (2003), available at <http://onlinelibrary.wiley.com/doi/10.1002/bmb.2003.494031010165/full>, archived at <http://perma.cc/N969-86A4>.

as provide an estimate of how many said citations were affected by reference rot.

We documented a serious problem of reference rot: more than 70% of the URLs within the above mentioned journals, and 50% of the URLs within U.S. Supreme Court opinions suffer reference rot — meaning, again, that they do not produce the information originally cited.

Given both of these problems, in this paper we propose a solution for authors and editors of new scholarship that will secure the long-term integrity of cited sources by involving libraries in a distributed, long-term preservation of link contents.

Perma.cc, developed by the Harvard Library Innovation Lab, is a caching solution to be used by authors and journal editors in order to integrate the preservation of cited material with the act of citation. Upon direction from a paper author or editor, Perma will retrieve and save the contents of a webpage, and return a permanent link. When the work is published, the author can include that permanent citation in addition to a citation to the original URL, or just the permanent link, ensuring that even if the original is no longer available because the site goes down or changes, the cache is preserved and available.

Other services have offered permanent citations before.⁴ But those services themselves become vulnerabilities within a citation system if their own long-term viability is not assured. Perma mitigates this vulnerability by distributing the Perma caches, architecture, and governance structure to libraries across the world. Thus, so long as any library or successor within the system survives, the links within a Perma architecture will remain.

PREVIOUS WORK

Much of the previous research on link rot was done in the early 2000s as citation of online materials rapidly increased. In 2002, Professor Mary Rumsey studied citations in legal materials, and concluded that as the citation of URLs was increasing, so too was link rot.⁵ At the time of her 2002 study she found a steady decrease in working links, with 61% of links from articles published in the previous year working, to only 30% working from five years earlier.⁶

Other studies, including by Professor Wallace Koehler from 2004, and by Professors John Markwell and David Brooks from 2006, are consistent with Rumsey's results, but apply to other domains: general

⁴ WEBCITE, <http://www.webcitation.org>, archived at <http://perma.cc/op7xfMNg8Kf>.

⁵ Rumsey, *supra* note 3, at 32, 34–35.

⁶ *Id.* at 35. Rumsey defines working links as links that take a viewer to the document or take a viewer to a list where the document appears. *Id.* at 31.

webpages and biochemistry, respectively.⁷ More recent work, including that of the Chesapeake Digital Preservation Group (CDPG) and Raizel Liebler and June Liebert's study of Supreme Court citations, recently published in the *Yale Journal of Law and Technology*, have concluded that link rot remains a significant problem.⁸

The CDPG has taken another approach to the study of link rot, while also taking important steps to preserve online resources.⁹ The CDPG does not seek to evaluate the link rot of a specific set of citations. Rather, since 2007, the CDPG has been caching documents that it anticipates might be used as legal resources, specifically for the purposes of studying link rot.¹⁰ Librarians associated with the CDPG select resources that they believe are worth collecting, and save a copy of those resources on their servers.¹¹ When conducting their link rot research, the team then compares the pages currently hosted at a URL with the cached copy.¹²

The CDPG's work is the most conclusive of the studies reviewed, due to its caching and comparison of digital resources. In its 2013 report, the CDPG found that 44% of the URLs from its original data set, including content collected between 2007 and 2008, no longer worked.¹³ The report does not mention whether a percentage of the links underwent reference rot — the content changing but the URL still resolving correctly. The CDPG also found that link rot in the sample was increasing over time.¹⁴

It may be difficult, however, to generalize the Chesapeake findings to more general legal citations, or to scholarship more broadly. The material captured by Chesapeake is specifically selected by archivists and librarians based on continuing relevance to legal scholarship. For example, Chesapeake's preserved documents include prepared pamphlets on government employee health insurance, a Soros report on HIV transmission criminalization, and a 1940 statement on principles

⁷ Koehler, *supra* note 3; Markwell & Brooks, *supra* note 3, at 70–71.

⁸ “Link Rot” and Legal Resources on the Web: A 2013 Analysis, CHESAPEAKE DIGITAL PRESERVATION GROUP (2013), <http://cdm16064.contentdm.oclc.org/ui/custom/default/collection/default/resources/custompages/reportsandpublications/2013LinkRotReport.pdf> (last visited Jan. 15, 2014); Liebler & Liebert, *supra* note 3, at 297–99.

⁹ Overview, CHESAPEAKE DIGITAL PRESERVATION GROUP, <http://cdm16064.contentdm.oclc.org/cdm/about#overview> (last visited Jan. 15, 2014), archived at <http://perma.cc/oL5yFmvwjaS>; see also Sarah Rhodes, *Breaking Down Link Rot: The Chesapeake Project Legal Information Archive's Examination of URL Stability*, 102 LAW LIBR. J. 581 (2010).

¹⁰ Rhodes, *supra* note 9, at 582.

¹¹ *Id.*

¹² *Id.*

¹³ “Link Rot” and Legal Resources on the Web: A 2013 Analysis, *supra* note 8.

¹⁴ *Id.*

of academic freedom.¹⁵ The materials cited in legal scholarship, on the other hand, may more typically reference popular media sources or individual webpages. But independent of the collection style, the CDPG's finding that over 50% of links to websites with government domains such as .gov and .mil no longer work does not bode well for citations to U.S. government websites.¹⁶

The work that most closely resembles our model is Liebler and Liebert's recently published study, which found that 29% of links cited in decisions of the Supreme Court of the United States from 1996–2010 were "invalid."¹⁷ As we will describe, our own tests of Supreme Court links revealed a much higher percentage of reference rot — 50%. The discrepancy is tied to three factors.¹⁸

First, we count both link rot and reference rot, while Liebler and Liebert count link rot only. Their method recorded the frequency with which a link returned an error page. We took the additional step of measuring reference rot, by manually examining apparently successful links to determine whether they produced their original sources.¹⁹

Second, time has elapsed since Liebler and Liebert tested their links, and even a few months can result in an increase in link rot.

And third, we included two more Supreme Court terms in our data set (OT 2010 and OT 2011).

OUR WORK

The threshold question of our work echoes Rumsey's: Are online citations in law reviews serving their intended purpose — to permit an interested reader to access the material cited in the journal?

Our answer is the same, but more conclusive: No. Of our spot-checked sample, only 29.9% of the *HRJ* links, 26.8% of the *HLR* links, and 34.2% of the *JOLT* links contained the material cited due to link or reference rot. We have no reason to expect that other journals are any different.

The links we evaluated in this study are to the open Web — that part of the Web that is accessible without paywalls or other restriction. Therefore, we did not check links to closed-access websites requiring passwords, such as references to well-known legal resources such as LexisNexis or Westlaw. The citation practices of the three journals we

¹⁵ *All Collections*, CHESAPEAKE DIGITAL PRESERVATION GROUP, <http://cdm16064.contentdm.oclc.org/cdm/search/collection> (last visited Jan. 15, 2014), archived at <http://perma.cc/oSvYRpDG26n>.

¹⁶ See "Link Rot" and *Legal Resources on the Web: A 2013 Analysis*, *supra* note 8.

¹⁷ Liebler & Liebert, *supra* note 3, at 298.

¹⁸ One less important additional factor is that our work was limited to resources available on the open Internet, whereas the Liebler and Liebert work was interested in citation more generally.

¹⁹ Liebler & Liebert, *supra* note 3, at 294.

tested are consistent with this research goal. At the time we tested the links, all three journals cited hard-copy versions of sources, such as cases published in reporters, and journal articles using the *Bluebook*-approved method of citation by volume number and printed pagination.²⁰ These citations of formal sources tend to omit URLs, anticipating that, inconvenience aside, readers can access the source in its printed version, or through an online resource, such as LexisNexis or Westlaw.²¹ Therefore, the “available at” URLs within these journals tend to link to public news articles, government documents, or other works not systematically available in print. Some also link directly to websites as proof of the matter asserted — for example, citing to a corporate home page or history for information about a corporation not available from a scholarly source.²²

Because our study involved a more extensive two-step review (first validating the links, and then for valid links, verifying the material cited is what was originally intended), we were able to consider a more general question about link rot: how comprehensive are HTTP status codes for predicting whether a given webpage is still working? Can such codes be used to successfully evaluate whether a linked source has evaporated?

HTTP status codes are sent from the webpage’s server to a browser that attempts to navigate to a page. The most popularly known is 404, or “not found,” but there are a number of others. For example, a 200 means that the server returned a page as expected, and a 503 indicates that the service is unavailable.²³ Status codes are easy to check in an automated fashion, so a successful attempt at pairing error codes with content or establishing a baseline understanding of error codes versus link rot could assist in future studies.

²⁰ See the article submission policies of each of the journals: *Submissions*, HARV. L. REV., <http://www.harvardlawreview.org/submissions.php> (last visited Jan. 15, 2014), *archived at* <http://perma.cc/42FG-NGWE>; *Submissions*, HARV. HUM. RTS. J., <http://harvardhrj.com/about/submissions> (last visited Jan. 15, 2014), *archived at* <http://perma.cc/8EAA-U5UH>; *Submissions*, HARV. J.L. & TECH., <http://jolt.law.harvard.edu/submissions> (last visited Jan. 15, 2014), *archived at* <http://perma.cc/JVM5-WCMD>.

²¹ See, e.g., THE BLUEBOOK: A UNIFORM SYSTEM OF CITATION R. 16, at 146 (Columbia Law Review Ass’n et al. eds., 19th ed. 2010).

²² At the time that we pulled data, the HLR did not include URLs for sources that were accessible in print, like *New York Times* articles. JOLT uses parallel citations to print available sources, as does HRJ.

²³ Roy T. Fielding et al., *Hypertext Transfer Protocol — HTTP/1.1, RFC2616*, WORLD WIDE WEB CONSORTIUM, <http://www.w3.org/Protocols/rfc2616/rfc2616-sec10.html> (last visited Jan. 15, 2014), *archived at* <http://perma.cc/QP8S-8HJN>.

HTTP Status	HLR	HRJ	JOLT
200 (working)	350	303	348
OPEN	187	109	191
400	22	-	-
404	308	253	291
403	65	-	122
All other codes	All	All	All

We found that some error codes are better than others. As expected, a complete lack of connection, or a 400 or 500 code (including 404, 503, etc.), is almost always a sign of link rot (the only exception being if a webpage is down temporarily). However, a 200 “all clear” signal does not mean that a source is present. A 200 can accompany a page displaying regrets, such as a custom 404-style page deployed by a website that does not return a 404 status (a soft 404).²⁴ It can also be a redirect, such as when a website has been overhauled since the citation and entire sets of pages have been redirected to the homepage. Of course, the page can also have changed in content but still be served up — this being the hardest to detect of the 200 problems and the most difficult form of reference rot to catch. Of the 353 “200 status” links within the Supreme Court corpus that we viewed and coded, only 76% still led to the cited material, indicating that reference rot independent of link rot is a major problem.

DETAILED METHODOLOGY AND DATA

Law Review Citations

On September 7, 2012, our team pulled all articles from the *Harvard Law Review*, *Harvard Journal of Law and Technology* and the *Harvard Law School Human Rights Journal*, starting in 1999, 1996, and 1997, respectively, until the summer of 2012. We isolated all of the footnotes, and then eliminated all footnotes that did not contain hyperlinks. Each of the hyperlinks was thus tied to a specific journal and footnote, and each hyperlink was counted only once. We then ran an HTTP status check as a first step to determine if the links were no longer functional, returning an error. If the domain for the URL no longer existed, the status checker returned a specific error (“OPEN”), also indicating that link was not functional.

²⁴ The term “soft 404” was explained extensively in an earlier paper on web decay. See Ziv Bar-Yossef, et al., *Sic Transit Gloria Telae: Towards an Understanding of the Web's Decay*, PROC. 13TH INT'L CONF. ON WORLD WIDE WEB 329 (2004).

After the HTTP status for all URLs had been coded, we selected a sample to check by hand. We first determined the proper sample size for a 5% margin of error for each HTTP status code. We then chose a random sample that included enough of each type of error code for each journal.

Each URL marked for spot-checking was loaded into a browser, and a single research assistant checked the page contents to see if it matched what the footnote promised. The research assistant coded the page as working if the URL still returned the expected information, and as not working if it did not. In most cases, the results were very easy to determine, given the level of specificity of the footnote and the contents of the site. However, it was impossible to truly determine in some cases whether the cited material was still present, in which case we tended to mark the material as not available. We did not make efforts to retrieve the information if it was not immediately present — however, some slight parsing mistakes that were introduced during the URL collection process were fixed.

We also recorded some additional information about the pages demonstrating reference rot by tagging them to categorize the changes they revealed. For example, pages that redirected to the home page of the domain were noted with a “redirect” tag, whereas pages that had clearly been archived (via a notice in the text of the page) were noted with an “archive” tag. The tagging process did not include all the possible variations of reference rot that could happen to linked pages, but it did allow us to have a better understanding of what happened to those webpages over the course of time.

Overall, we found that link rot was a large problem for all three journals studied. From the initial status code check, only 65% of *HLR* links returned a working page (indicated by a “200” code), along with 60% of *HRJ* links, and 67% of *JOLT* links. Below are tables with the status code results from the three journals.²⁵

²⁵ See Appendix 1 for a list of HTTP status code meanings. “OPEN,” which is not an HTTP status code, means the server did not return anything.

Tag	HRJ	JOLT	HLR
200–OK	59.9%	65.2%	66.8%
404–Not Found	31.2%	26.1%	21.9%
OPEN–No Server Response	6.4%	6.1%	7.0%
403–Forbidden	0.9%	1.3%	3.3%
400–Bad Request	0.5%	0.4%	0.2%
500–Internal Server Error	0.5%	0.4%	0.3%
All Others	0.7%	0.5%	0.8%

Spot-checked data revealed that even pages with no link rot had undergone reference rot. URLs that appeared to be valid (returning a 200 status code to our status checker) nonetheless frequently redirect to another page, or were actually 404 pages that did not return the correct status in the initial check. This is just link rot in disguise. In other cases, the pages seemed fine, but did not contain the materials that were originally cited, as in the “Working (updated)” tag, indicating reference rot.

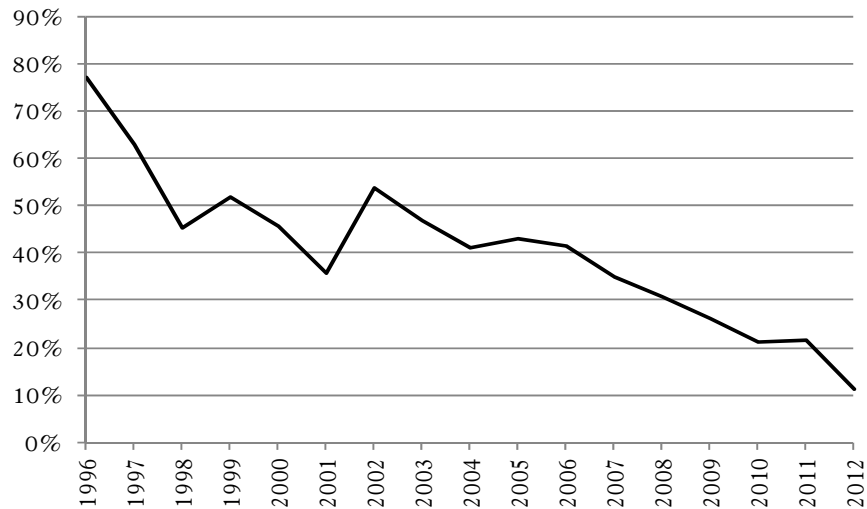
Only 29.9% of the *HRJ* links, 26.8% of the *HLR* links, and 34.2% of the *JOLT* links in our sample contained the material cited. Given that this sample included the ~60% of 200 links, this was much lower than expected, and significantly different from the numbers expected based on the status codes. Below is the breakdown of the results from the spot-check of pages that originally produced a 200 status code.

Tag	HRJ	JOLT	HLR
200–Working	64%	66%	68%
200–Redirect	22%	15%	14%
200–Custom 404	7%	8%	11%
200–Working (updated)	0%	8%	6%
200–Blank Page	3%	1%	0%
200–Assorted Other	4%	2%	1%
Total	303	348	350

There was some variation in link rot/reference rot rates by journal, although it is difficult to tell if this is because of subject material or due to some other factor, such as publication rates or citation checking. Of the three journals, *JOLT* started using hyperlinks in footnotes first. *JOLT* and *HLR* have similar numbers of total hyperlinks; however,

JOLT publishes twice yearly,²⁶ and *HLR* publishes eight times per year²⁷ — meaning that per issue, *JOLT*'s number of links is much higher. *HRJ* only publishes once per year.²⁸ The linked materials do not differ to significantly across subject fields, however, it may be that technology websites or news sources of the type cited by *JOLT* authors are more careful to preserve URLs than the types of sources included in *HLR* or *HRJ*.

Consistent with previous findings, we also found that the number of links with either reference or link rot increases with the age of the publication. The chart below illustrates the percentage of broken links per year (note that the 2012 data is incomplete):



²⁶ *Articles*, HARV. J.L. & TECH., <http://jolt.law.harvard.edu/articles> (last visited Jan. 15, 2014), archived at <http://perma.cc/D73W-9AWB>.

²⁷ *About*, HARV. L. REV., <http://www.harvardlawreview.org/about.php> (last visited Jan. 15, 2014), archived at <http://perma.cc/8MCP-F6PX>.

²⁸ *About*, HARV. HUM. RTS. J., <http://harvardhrj.com/about> (last visited Jan. 15, 2014), archived at <http://perma.cc/oQMWnM4Lhxs>.

*Supreme Court Citations***SCOTUS Status Codes**

Tag	Count	Percent
200	353	63.6%
OPEN	56	10.1%
404	136	24.5%
403	6	1.1%
Other	4	0.7%
Total	555	

Breakdown of 200 Code URLs

Tag	Count	Percent
Cited Material	277	78.5%
Redirect	32	5.8%
Blank Page	3	0.5%
Custom 404	29	5.2%
Updated	5	0.9%
Other	7	1.3%
Total	353	

On June 26, 2013, our team obtained a database of all Supreme Court opinions from CourtListener.²⁹ We then found all of the URLs in that text, first by using a regular expression search technique to identify all links, and second, by checking the data by hand to eliminate duplicates. This returned 555 hyperlinks, the first appearing in *Denver Area Educational Telecommunications Consortium, Inc. v. FCC*³⁰ from 1996. We checked the HTTP status for each citation, finding that 63.6% returned a 200.

Over the following two days, our research assistants spot-checked all links returning a 200, a refinement based on our earlier methodology, using the original footnotes to determine the information that the Supreme Court had intended to cite. Each link was coded by a single research assistant.

Our finding is that 49.9% of the links cited in the Supreme Court opinions no longer had the cited material. So again, while many of the

²⁹ COURT LISTENER, <https://www.courtlistener.com> (last visited Nov. 24, 2013), archived at <http://perma.cc/oFXzJ8DpvKs>.

³⁰ 518 U.S. 727 (1996).

links were technically valid — they did, in fact, return webpages — many either did not contain the information originally cited or contained information that had changed materially.

DISCUSSION

When devising a solution for link rot and reference rot, it is important to keep in mind the different reasons why a link may no longer resolve properly. Other sources have documented many issues,³¹ but we will reiterate a few that we found in our work.

First, websites are often reorganized, and such reorganizations can impact scholarship significantly. This is true even for websites of organizations that have a considerable influence on the law or have considerable historical significance. For example, the International Criminal Tribunal for the former Yugoslavia (ICTY) originally kept its documents on a subpage of the United Nations website.³² Many *HRJ* articles referenced these documents, using those UN.org addresses. In 2001, the ICTY moved to ICTY.org, and all of the individual document links now redirect to the top-level ICTY homepage.³³ That change requires the reader to engage in a complex search to find an original document again. Thus, and perhaps ironically, it is easier to find documents related to war crimes that predate the “information age” than documents about war crimes that were first published on the Web.³⁴

Second, control of a website is sometimes handed over to a different organization, again often creating havoc for citations. For example, the overhaul of whitehouse.gov now results in all press release links from the early 2000s redirecting to the home page for the White House press office.

Third, the organizations or companies originally hosting the cited material sometimes go defunct, either putting their domain names up for sale, or ceasing to run servers. Or they go effectively defunct, if only for a short period. The U.S. federal government, for example, was partially shut down in late 2013, with thousands of formerly stable webpages at .gov destinations temporarily no longer available. Or

³¹ See, e.g., Frank McCown, Catherine C. Marshall & Michael L. Nelson, *Why Web Sites Are Lost (and How They're Sometimes Found)*, COMM. ACM, Sept. 2009, at 141.

³² E.g. Prosecutor v. Rajic, Indictment (Int'l Crim. Trib. For the Former Yugoslavia Aug. 23, 1995), <https://web.archive.org/web/20070528065139/http://www.un.org/icty/indictment/english/raj-ii950829e.htm> (last visited Jan. 15, 2014).

³³ E.g. United Nations International Criminal Tribunal for the former Yugoslavia, <http://www.un.org/icty/indictment/english/raj-ii950829e.htm> (last visited Jan. 15, 2014).

³⁴ For a list of the major print primary sources for the Nuremberg Trials, see *Nuremberg Trials Resources*, HARV. L. SCHOOL LIBR. NUREMBERG TRIALS PROJECT, http://nuremberg.law.harvard.edu/php/docs_swi.php?DI=1&text=bibliogr (last updated Feb. 2003), archived at <http://perma.cc/ZKD7-DYCC>.

they simply render the cited link useless. The URL ssnat.com, for example, was originally cited in a 2011 Supreme Court case. Since 2011, the site has become a commentary on the link itself: it now contains only a message mentioning the Supreme Court opinion and musing about the ephemerality of information.³⁵

Finally, and potentially most Orwellian, sometimes website owners update the same page with new information and do not indicate that the material has changed, or do not include the date of the update. The White House, for example, has been charged with modifying press releases, but has not indicated that the documents were changed.³⁶ And the Corporation for Public Broadcasting updates its website with new information about the number of stations and affiliates it has. However, because the update is not dated, it is not clear from the page whether it has been updated since cited in *FCC v. Fox Television Stations, Inc.*³⁷ in 2009, thus producing a discrepancy between the fact on the website and the fact as cited in the opinion. Commentators have previously raised concerns about the mutability of web content, noting that a blogger cited in a court opinion could edit the content to completely change it, or even add different facts or information.³⁸ Even worse, sometimes the change is immediate, as when the website cited is a database, meaning that every time someone clicks on a link, the results are live.

These findings, and previous research, establish a compelling case that link rot and reference-rot in online citations are significant and increasing problems. Any solution to link and reference rot will have to address the impermanence of the Web, the havoc caused by organizational change (including webpage reorganization), handovers of domain names (and domain name sale), and successful citation practices.

³⁵ When readers visit the link, they find a page that says “Aren’t you glad you didn’t cite to this webpage in the Supreme Court Reporter at *Brown v. Entertainment Merchants Association*, 131 S.Ct. 2729, 2749 n.14 (2011). If you had, like Justice Alito did, the original content would long since have disappeared and someone else might have come along and purchased the domain in order to make a comment about the transience of linked information in the internet age.” 404 *Error — File Not Found*, <http://ssnat.com/>, archived at <http://perma.cc/ogwuuqRxEJJW>.

³⁶ Scott Althaus & Kaley Leetaru, *Airbrushing History, American Style*, CLINE CENTER FOR DEMOCRACY (Nov. 25, 2008), http://www.clinecenter.illinois.edu/airbrushing_history, archived at <http://perma.cc/G8PW-798L>.

³⁷ 129 S. Ct. 1800, 1836 (2009) (Breyer, J., dissenting).

³⁸ See, e.g., Lee F. Peoples, *The Citation of Blogs in Judicial Opinions*, 13 TUL. J. TECH. & INTELL. PROP., 39, 73.

ADDRESSING LINK ROT: PERMA

Given the distributed nature of the Internet, both link and reference rot is inevitable.³⁹ Based on the studies referenced above, and the additional work we have done, it should be clear that both are serious problems for scholarship.

Some researchers have suggested solutions for link rot, specifically as applied to law reviews — following other scholarly fields by adopting Digital Object Identifiers (DOIs) in the citations of legal articles.⁴⁰ DOIs solve a number of problems with URL citation — they provide the same level of traceability and persistence as a journal edition number or court citation while working for a variety of formats. For items where a DOI will work or already exists, including scholarly works and research datasets, a DOI in a citation can be very helpful.

DOIs have not gained traction within the legal community, however. Not only are they not suggested by *The Bluebook*, they are not even mentioned by that citation resource at all.⁴¹ DOIs may be a promising solution for law review articles as printed volumes become less and less popular, leaving citation to proprietary databases as the alternative. However, for pages on the open web, a DOI system is impractical, requiring a high level of buy-in from document publishers such as webmasters, bloggers, and newspapers, many of whom are likely to be indifferent to the problems of posterity.

Another suggested solution includes using the Internet Archive to preserve pages of scholarly importance. The Archive already repeatedly crawls as much of the Web as it can, preserving whatever it can from what it finds.⁴² This has some value for many links that are

³⁹ Of course, conscientious website owners can take steps to prevent it. For example, when moving to a new URL scheme or website organization, owners can keep old links with archived previous versions of pages, or make the redirection process transparent. Realizing that government-published materials may be widely cited, governments creating new URL schemes should be especially careful to preserve the accessibility of older materials.

⁴⁰ See Benjamin J. Keele, What if Law Journal Citations Included Digital Object Identifiers?, (Mar. 18, 2010) (unpublished manuscript) available at <http://dx.doi.org/10.2139/ssrn.1577074>; Susan Lyons, *Persistent Identification of Electronic Documents and the Future of Footnotes*, 97 LAW LIBR. J. 681 (2005).

⁴¹ This distinguishes *The Bluebook* and legal citation from many of the other citation styles in other fields, which allow DOIs. In fact, the APA style requires the use of DOIs if available. See PUBLICATION MANUAL OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION (6th ed. 2010); THE CHICAGO MANUAL OF STYLE § 14.6 (16th ed. 2010).

⁴² *The Wayback Machine: FAQ*, INTERNET ARCHIVE, http://archive.org/about/faqs.php#The_Wayback_Machine (last visited Jan. 15, 2014), archived at <http://perma.cc/oV2j3ibrkrG> (“Why isn’t the site I’m looking for in the archive?: Some sites may not be included because the automated crawlers were unaware of their existence at the time of the crawl. It’s also possible that some sites were not archived because they were password protected, blocked by robots.txt, or otherwise inaccessible to our automated systems. Siteowners might have also requested that their sites be excluded from the Wayback Machine. When this has occurred, you will see

broken, and methods, including existing browser plug-ins, exist for re-directing users to older versions of pages.⁴³ A standard to include temporal information for archived pages, like the one suggested by the team behind Memento, could make this effort even more effective.⁴⁴

However, the Internet Archive only occasionally trawls and stores any given corner of the internet, meaning there is no guarantee that a given page would be archived to reflect what an author or editor saw at the moment of citation. Moreover, the Internet Archive is only one organization, privately funded and voluntarily supported, and there might be long-term concerns around relying upon its continued existence. A system of distributed, redundant ownership and storage is an obviously a better long-term solution — and indeed, the Internet Archive has shown itself ready to partner on archiving ventures in addition to its own efforts.⁴⁵

Finally, some publishers and scholars have adopted an archival/permalink approach similar to the one described at the beginning of this paper. For example, WebCite, a service run by Professor Gunther Eysenbach at the University of Toronto, has been serving as a central repository for caching documents for medical journals and other sources for a number of years.⁴⁶ WebCite partially mitigates the issue of sporadic archiving since individuals can create WebCite links directly, or journals can feed their archives through WebCite to save a version of their pages.

But as with the Internet Archive, WebCite too is a single source solution to a problem that could benefit from redundancy. Despite its goal of permanence, the project has threatened to stop accepting new URLs unless it receives donations.⁴⁷ Given the importance of scholarly documents, the integrity of scholarship requires more assurance that the archive will stay open.

Additionally, although WebCite allows for individuals to store pages, its intake method for journal links means that there is no guarantee

a ‘blocked error’ message. When a site is excluded because of robots.txt you will see a ‘robots.txt query exclusion error’ message.”)

⁴³ See *Adding Time to the Web*, MEMENTO, <http://mementoweb.org/> (last visited Jan. 15, 2014), available at <http://perma.cc/09Z5S1xWjLH>; see also H. Van de Sompel, *HTTP Framework for Time-Based Access to Resource States*, MEMENTO (Dec. 2013), <http://www.mementoweb.org/guide/rfc/ID/>, archived at <http://perma.cc/oXcKmZfbQat>.

⁴⁴ See Herbert Van de Sompel, Martin Klein, Robert Sanderson & Michael Nelson, *Thoughts on Referencing, Linking, Reference Rot*, MEMENTO, <http://mementoweb.org/missing-link/> (last visited Jan. 15, 2014), archived at <http://perma.cc/DUB4-VNYM>.

⁴⁵ See *Archive-It — Learn More*, INTERNET ARCHIVE, <https://archive-it.org/learn-more/> (last visited Jan. 15, 2014), archived at <http://perma.cc/W3T9-ZSH3>.

⁴⁶ *WebCite Consortium FAQ*, WEBCITE, <http://www.webcitation.org/faq> (last visited Jan. 15, 2014), archived at <http://perma.cc/ojRLzTskc8o>.

⁴⁷ See WEBCITE, <http://www.webcitation.org/> (last visited Jan. 15, 2014), archived at <http://perma.cc/op7xFMNg8Kf>.

that that material it is caching is the actual intended cited material. Reference rot could have already occurred before caching, or the URL cited could otherwise not return the expected material. For example, larger and larger portions of the Web are personalized or display regional content. The lack of a human element in ensuring the stored material is what the author intended to cite is as much a problem for a solution as it is for accurately measuring the extent of reference rot.

In addition to WebCite, there is another project already working in this space — Archive.is, which advertises itself as a “personal Way-back Machine” and contains a searchable archive of previously captured webpages.⁴⁸ Archive.is does not seem to suffer from the same funding problems as WebCite, but may suffer from a lack of institutional backing.⁴⁹ And it again is a single source solution, which is vulnerable to the changing mission of its founding organization.

PERMA

The solution we propose is a platform that will allow authors and editors to automatically generate, store, and reference — in a freely and publicly accessible manner — archived data representing the relevant information of a cited online resource. A freely accessible web database of cited materials will not only allow for the owners of websites to no longer worry about maintaining cited links, it will create better references and more easily verified scholarship.

Just as a reference in a law review article published in the 1920s is still retrievable today — at least with the help of a well-equipped library — websites and online materials cited in today’s scholarship should exist for verification indefinitely. And most importantly, Perma is built with the support of a consortium of dozens of law school libraries, as well as nonprofit entities such as the Internet Archive and Digital Public Library of America, to ensure that links to all cited materials will remain without change and in perpetuity.

Perma uses the citation process itself as a solution to link rot. As the author cites the material, the author can provide a link to Perma, and the Perma server will save a copy of the information

⁴⁸ ARCHIVE.IS, <http://archive.is/> (last visited Jan. 15, 2014), archived at <http://perma.cc/oyezTLau6VK>.

⁴⁹ See the Archive.is frequently asked questions page, which states, in part, “[Archive.is] is privately funded; there are no complex finances behind it. It may look more or less reliable compared to startup-style funding or a university project, depending on which risks are taken into account. My death can cause interruption of service, but something like new market conditions or changing head of a department cannot.” *FAQ*, ARCHIVE.IS, <http://archive.is/faq.html> (last visited Jan. 15, 2014), archived at <http://perma.cc/oA72qhQbNAE>.

relevant to the citation — at that address at that particular time — thereby capturing what the author determined was a source requiring the citation. Perma will then return to the author a new link, and a formal citation, which is designed to last as long as the Perma system survives. That link can then be used in the work, either in addition to the original citation, or instead of the original citation.

When a reader then follows the new permanent link, she will see a number of pieces of basic metadata, in addition to the content presently available at the original source. That metadata will include the time and date the author made the original citation, along with the citing author and publication.

For dynamic or personalized content, Perma can retain a copy of the content that the author originally experienced, at least to the extent it is relevant to providing a citable resource, and will not need to rely on the original site to continue to serve content or material. An author may also be able to upload a screenshot of content he or she viewed, providing access to an advertisement or other piece of content that would be hard to replicate by accessing the dynamic page independently.

Perma will be designed to run harmoniously with paywalls and other business models and practices common to the open Web. When you access a Perma link, you will first be directed to the original page; the Perma cache will only be accessed if the link no longer serves the original content. If for some reason the original site's content should not be displayed publicly, Perma will respect that by only serving them up to users through a manual reference process brokered by the hosting library.⁵⁰

Each institution using Perma will have an associated library that vouches for the journal's authenticity and scholarly value. This design will help manage the number of cached links, as well as demonstrate the libraries' commitment to preservation of scholarly works and sources. The project may also expand to other disciplines if additional libraries can support it. Perma will also support the Memento protocol, allowing it to integrate into existing efforts to allow recovery of cached webpages.⁵¹

⁵⁰ This process will permit sites archived by Perma to take down allegedly copyright-infringing or defamatory material while allowing librarians to provide it to potential readers with due care.

⁵¹ See MEMENTO, *supra* note 43; *Chrome Web Store—Memento Time Travel*, <https://chrome.google.com/webstore/detail/memento/jgbfpjledahoajcppakbgilmojkaghgm> (last visited Jan. 21, 2014), archived at <http://perma.cc/P6GP-GJZQ> (describing and linking to the Memento for Chrome extension that allows for page retrieval); Hvdsonp, *Memento Extension for Chrome: A Preview* (Sept. 9, 2013), <http://www.youtube.com/watch?v=WtZHKeFwjzk> (demonstrating the use of the Memento for Chrome extension).

CONCLUSION

The rise of the Web has enabled the creation and exchange of scholarly knowledge and the sources on which it is based. It has also bypassed the libraries that previously vouchsafed the long-term preservation of those sources. Unless action is taken to archive this type of information, future readers will be unable to obtain the sources relied upon by the authors whose work they read. The integrity of scholarship will suffer. The distributed Perma system seeks to unite journals, libraries, and authors to restore that integrity by ensuring that those sources are appropriately preserved for posterity.

APPENDIX I: RELEVANT HTTP STATUS CODES⁵²**10.2.1 200 OK**

The request has succeeded. The information returned with the response is dependent on the method used in the request, for example:

GET an entity corresponding to the requested resource is sent in the response;

HEAD the entity-header fields corresponding to the requested resource are sent in the response without any message-body;

POST an entity describing or containing the result of the action;

TRACE an entity containing the request message as received by the end server.

10.4.1 400 Bad Request

The request could not be understood by the server due to malformed syntax. The client SHOULD NOT repeat the request without modifications.

10.4.2 401 Unauthorized

The request requires user authentication. The response MUST include a WWW-Authenticate header field (section 14.47) containing a challenge applicable to the requested resource. The client MAY repeat the request with a suitable Authorization header field (section 14.8). If the request already included Authorization credentials, then the 401 response indicates that authorization has been refused for those credentials. If the 401 response contains the same challenge as the prior response, and the user agent has already attempted authentication at least once, then the user SHOULD be presented the entity that was given in the response, since that entity might include relevant diagnostic information. HTTP access authentication is explained in “HTTP Authentication: Basic and Digest Access Authentication.”⁵³

10.4.4 403 Forbidden

The server understood the request, but is refusing to fulfill it. Authorization will not help and the request SHOULD NOT be repeated. If the request method was not HEAD and the server wishes to make public why the request has not been fulfilled, it SHOULD describe the reason for the refusal in the entity. If the

⁵² Excerpted from Fielding et al., *supra* note 23.

⁵³ J. Franks et al., *HTTP Authentication: Basic and Digest Access Authentication*, INTERNET ENGINEERING TASK FORCE (June 1999), <http://tools.ietf.org/pdf/rfc2617.pdf>, archived at <http://perma.cc/5TMQ-64KF>.

server does not wish to make this information available to the client, the status code 404 (Not Found) can be used instead.

10.4.5 404 Not Found

The server has not found anything matching the Request-URI. No indication is given of whether the condition is temporary or permanent. The 410 (Gone) status code SHOULD be used if the server knows, through some internally configurable mechanism, that an old resource is permanently unavailable and has no forwarding address. This status code is commonly used when the server does not wish to reveal exactly why the request has been refused, or when no other response is applicable.

10.4.6 405 Method Not Allowed

The method specified in the Request-Line is not allowed for the resource identified by the Request-URI. The response MUST include an Allow header containing a list of valid methods for the requested resource.

10.4.11 410 Gone

The requested resource is no longer available at the server and no forwarding address is known. This condition is expected to be considered permanent. Clients with link editing capabilities SHOULD delete references to the Request-URI after user approval. If the server does not know, or has no facility to determine, whether or not the condition is permanent, the status code 404 (Not Found) SHOULD be used instead. This response is cacheable unless indicated otherwise.

The 410 response is primarily intended to assist the task of web maintenance by notifying the recipient that the resource is intentionally unavailable and that the server owners desire that remote links to that resource be removed. Such an event is common for limited-time, promotional services and for resources belonging to individuals no longer working at the server's site. It is not necessary to mark all permanently unavailable resources as "gone" or to keep the mark for any length of time — that is left to the discretion of the server owner.

10.4.17 416 Requested Range Not Satisfiable

A server SHOULD return a response with this status code if a request included a Range request-header field (section 14.35), and none of the range-specifier values in this field overlap the current extent of the selected resource, and the request did not include an If-Range request-header field. (For byte-ranges, this means that the first-byte-pos of all of the byte-range-spec values were greater than the current length of the selected resource.)

When this status code is returned for a byte-range request, the response **SHOULD** include a Content-Range entity-header field specifying the current length of the selected resource (see section 14.16). This response **MUST NOT** use the multipart/byteranges content-type.

10.5.1 500 Internal Server Error

The server encountered an unexpected condition which prevented it from fulfilling the request.

10.5.3 502 Bad Gateway

The server, while acting as a gateway or proxy, received an invalid response from the upstream server it accessed in attempting to fulfill the request.

APPENDIX 2: BREAKDOWN OF HTTP STATUS CODES BY
JOURNAL

HRJ

Code	Frequency	Percentage	Cumulative
200	1,412	59.88	59.88
404	736	31.21	91.09
OPEN	150	6.36	97.46
403	21	0.89	98.35
400	11	0.47	98.81
500	11	0.47	99.28
302	4	0.17	99.45
502	3	0.13	99.58
UNKNOWN	3	0.13	99.7
303	2	0.08	99.79
401	2	0.08	99.87
410	2	0.08	99.96
415	1	0.04	100
Total	2,358	100	

HLR

Code	Frequency	Percentage	Cumulative
200	3,855	65.22	65.22
404	1,543	26.1	91.32
OPEN	362	6.12	97.45
403	78	1.32	98.77
400	23	0.39	99.15
500	23	0.39	99.54
302	10	0.17	99.71
UNKNOWN	6	0.1	99.81
410	5	0.08	99.9
301	2	0.03	99.93
401	2	0.03	99.97
300	1	0.02	99.98
503	1	0.02	100
Total	5,911	100	

JOLT

Code	Frequency	Percentage	Cumulative
200	3,627	66.82	66.82
404	1,190	21.92	88.74
OPEN	377	6.95	95.69
403	177	3.26	98.95
500	15	0.28	99.23
400	8	0.15	99.37
302	5	0.09	99.47
410	5	0.09	99.56
503	5	0.09	99.65
401	4	0.07	99.72
UNKNOWN	4	0.07	99.8
300	3	0.06	99.85
400	8	0.15	99.37
301	3	0.06	99.91
415	2	0.04	99.94
303	1	0.02	99.96
416	1	0.02	99.98
502	1	0.02	100
Total	5,428	100	

APPENDIX 3: BREAKDOWN OF 200 STATUS
CODE TAGS BY JOURNAL

HRJ

Tag	Frequency	Percentage
200-Working	195	64.36
200-Redirect	67	22.11
200-Custom 404	22	7.26
200-Blank Page	8	2.64
200-Domain for Sale	4	1.32
200-Assorted Error	3	0.99
200-Archived	2	0.66
200-Paywall	2	0.66
Total	303	

HLR

Tag	Frequency	Percentage
200-Working	237	67.71
200-Redirect	49	14.00
200-Custom 404	39	11.14
200-Working (updated)	22	6.29
200-Domain for Sale	2	0.57
200-Unclear	1	0.29
200-Paywall	1	0.29
Total	350	

JOLT

Tag	Frequency	Percentage
200-Working	228	65.52
200-Redirect	53	15.23
200-Custom 404	28	8.05
200-Working (updated)	27	7.76
200-Blank Page	4	1.15
200-Domain for Sale	2	0.57
200-DNS Lookup Failed	2	0.57
200-Archived	1	0.29
200-500 Error	1	0.29
200-Forbidden	1	0.29
200-Paywall	1	0.29
Total	348	