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# Technical Standards and a Theory of Writing as Infrastructure

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## Abstract

Infrastructures support and shape our social world, but they do so in often invisible ways. In few cases is that truer than with various documents that serve infrastructural functions. This article takes one type of those documents—technical standards—and uses analysis of one specific standard to develop theory related to the infrastructural function of writing. The author specifically analyzes one of the major infrastructures of the Internet of Things—the 126-page Tag Data Standard (TDS)—to show how rethinking writing as infrastructure can be valuable for multiple conversations occurring with writing studies, including research on material rhetoric, research that expands the scope of what should be studied as writing, and research in writing studies that links with emerging fields. The author concludes by developing a model for future research on the infrastructural functions of writing.

## Keywords

writing theory, infrastructure studies, technical communication, technical standards, Internet of Things

I looked up information on my laptop more times than I could count while writing this article. The information appeared on my screen as if by magic; I typed something and it showed up. But far beneath the level of the screen

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interface, the information I accessed was enabled by a variety of standards—that is, documents that provide guidelines, definitions, and production practices that make interoperability possible across a range of industries—that determined everything from my computer's IP address to the wireless protocols of my router to the dimensions of the fiber optic cable. And Internet standards are just one of many types of standards that enabled me to write this article. With little exaggeration, all of our lives are shaped by hundreds (if not thousands) of standardized objects (Busch, 2011).

Standards mostly remain out of view; even when people have a vague idea a standard exists (e.g., IpV4 or IpV6),[1] they rarely know what it says. And standards are not unique in that invisibility. Many types of writing play crucial and yet unnoticed roles in how the world works. People may never see all the documentation that goes into the code behind a piece of software, the memo to management addressing a design flaw, or the user experience reports that shape the look and feel of a website. But those documents nonetheless contribute to an infrastructure upon which a final product is built, even if that base is not visible to the end user. Similarly, standards may remain mostly invisible, but they are a potentially valuable object of attention for writing studies research. After all, they are a ubiquitous, consequential type of writing that shapes our material world through language while simultaneously remaining mostly out of view. As such, standards are an object of study through which researchers can explore how writing shapes our everyday lives in powerful but often unseen ways.

Standards work as what I call "discursive infrastructure," a term that builds on Sarah Read's (2019) relational theory of infrastructural writing. I use the term here to explore technical standards as a form of discursive infrastructure that can help develop a broader theory of writing as infrastructural. These documents shape the material world, support actions built upon the texts, and possibly most importantly from a relational perspective, are crucial infrastructures for supporting other infrastructures. But my goal is broader than to look only at standards; rather, I conclude the article by arguing that writing studies could benefit from adopting a more infrastructural way of thinking about writing that exposes the hidden work writing does to hold larger systems together. As I discuss throughout this article, developing an infrastructural theory of writing can

- build a theory of infrastructural writing that will help researchers better define what it means for writing to work as infrastructure (Read, 2019)
- link writing to conversations about material rhetoric by examining the role language plays in shaping the material world (Barnett & Boyle, 2016; Boyle, 2018; Ching, 2018; Frith, 2015)

- expand upon an existing strand of writing studies research that examines often ignored types of organizational writing, including engineering notes and medical records (Schryer, 1993; Winsor, 1994)
- extend the growing body of literature that examines infrastructure from a rhetorical perspective (Johnson, 2012; Johnson & Johnson, 2016)
- make the case for the value of writing studies research within the transdisciplinary field of infrastructure studies to help add to the ongoing discussion of interdisciplinarity in writing studies (Silva et al., 1997)
- build upon the work of scholars like Vee (2013) and Brock (2019) to broaden what counts as writing and text in the field of writing studies

To develop an infrastructural theory of writing, I begin by providing brief detail on standards. Standards can work as a link between research that looks at writing mostly from a linguistic perspective and research that engages more with the material dimensions of writing and rhetoric. Understanding the role standards play in shaping the world also can be an initial step in linking writing studies with the broader "infrastructural turn" that has shaped other disciplines, including media studies (Parks, 2012), anthropology (Larkin, 2013), and computer science (Dourish & Bell, 2007). I then discuss infrastructure studies to better situate how writing studies researchers can approach the study of infrastructure and, thereafter, present the methods used for this article. The analysis focused on the Tag Data Standard, which is the major standard for the Electronic Product Code and a key piece of the Internet of Things (Frith, 2019). I set out to explore the following question: "What rhetorical work does this standard do to support and shape the development of the Electronic Product Code?" After detailing the categories that emerged from the analysis, I conclude with a discussion that relates the data to the broader discussion of the role writing can play as relational discursive infrastructure. As I make clear, while this article looks specifically at standards, the main goal is to build a path toward future research that can analyze the infrastructural elements of other types of writing. Or to put it another way, the standard analyzed in this article—the Tag Data Standard—is one part of a larger story of the theoretical approach I develop regarding writing as infrastructure.

## The Importance of Standards

Much of the world is shaped by standards, from the way data are stored on a barcode to how a mobile phone connects to a network. These standards are published by various organizations, with a few of the major ones being the World Wide Web Consortium (W3C), the International Organization for Standardization (ISO), GS1, the International Telecommunications Union (ITU), and ASTM International. These organizations focus on different industries, but they all provide written documents meant to standardize specific objects—defined intentionally broadly to capture the diversity of nonhumans that move through the world—across companies.

Standards are defined differently depending on the source, but an official definition repeated in many technical texts comes from the U.S. federal government, which specifically defines standards as

- "Common and repeated use of rules, conditions, guidelines or characteristics for products or related processes and production methods, and related management systems practices."
- "The definition of terms; classification of components; delineation of procedures; specification of dimensions, materials, performance, designs, or operations; measurement of quality and quantity in describing materials, processes, products, systems, services, or practices; test methods and sampling procedures; or descriptions of fit and measurements of size or strength." (Office of Management and Budget, 2016, p. 5)

As the definitions make clear, these documents do everything from define terms to instruct readers on how to implement suggestions to provide processes for testing whether an object meets a standardized requirement. Importantly, standards also tend to be rather technical in nature, and the German Institute for Standardization points out that they "are not written for the general reader—anyone using standards should have enough technical knowledge that they can take reasonable responsibility for their actions" (Schmidt, 2018, n.p.). They are rhetorical documents written with specific audiences in mind.

While standards have not been a primary object of study in much writing studies research (with a few exceptions, discussed below), there is a significant body of academic research on standards in other disciplines. Many of these works build a theoretical base for understanding the role standards play in holding our social world together. For example, in a book on standardization, sociologist Laurence Busch (2011) argues that standards are the site "where language and world meet" and are "about the ways in which we order ourselves, other people, things, processes, numbers, and even language itself" (p. 3).

Busch's work provides an account of standardization through history and builds upon what is possibly the formative study of standardization: Bowker and Star's (1999) *Sorting Things Out.* These scholars examined the myriad ways systems of classification work as essential infrastructures that shape everything from medical manuals that define what counts as a disease to documents that define what counted as “race” in the complex sorting schemes of apartheid South Africa. While Bowker and Star are not rhetoricians, their work does tie implicitly to rhetoric, particularly Aristotle’s (1965) formative work on classification systems. Aristotle created taxonomies to classify all living organisms. His work essentially tried to standardize “classes” of living things to find common overlap and divergences. Similar to Bowker and Star’s work on classification systems, Aristotle’s taxonomies were early examples of how language could work as infrastructure that shaped the identification and sorting of objects and bodies throughout the world.

While standards are texts that translate information amongst diverse audiences, little research published in writing studies journals has studied them primarily for their content. Most often, writing research discusses how standards impact communication rather than analyzing standards as actual texts. For example, Hackos (1985) published an article on best practices for developing written standards in an organization. Later, Hackos (2016) made the case for why organizations should implement standards, writing that “standards help the community demonstrate that it has people working together worldwide to ensure that it defines and implements best practices in designing content and delivering it effectively” (p. 24).

Relatedly, writing studies research features both empirical and pedagogical approaches to standards (Warren, 2001; Youngblood, 2012). Maybe the most in-depth work to do so was Haas and Witte (2001). For instance, they used standards as a way to examine writing as an embodied practice, arguing that, “The standards document . . . is meant to codify expert knowledge . . . streamline decision making, and standardize the material reality of city infrastructure” (p. 419). In particular, their work looked at how a group of engineers worked with city planners to create standards documents that would later become key reference points for the development of crucial city systems. Haas and Witte’s work recognized the importance of standards and uses standards to develop writing theory more broadly. Similarly, I chose standards as an object of analysis because they are ubiquitous, play major roles in shaping social practices and the material world, and are understudied texts within writing studies. And equally importantly, like Haas and Witte, I use standards to help develop a theory of how writing works as discursive infrastructure, a concept I build by integrating writing studies research with the transdisciplinary field of infrastructure studies.

## Infrastructure Studies

Developing a theory of writing as infrastructure through textual data is important because most commonly, researchers—regardless of discipline—do not define infrastructure when they use the term; the meaning is assumed and rarely questioned. For example, Demchenko et al.'s (2013) article about big data infrastructures in the sciences has an entire section that defines big data, but no explicit definition of infrastructure. As an example from writing studies, Swarts's (2010) excellent work on recycled writing provides a complex analysis of how "distributed groups must build an infrastructure that enables a group to organize and function collectively" (p. 130). However, the article does not define how the term "infrastructure" is deployed. Even when the term is defined in research, it is typically used to focus on infrastructure as a rather straightforward substrate that supports a broad range of practices. There is certainly some truth to the popular definition, but infrastructure as a concept is much more complicated and inclusive (Dourish & Bell, 2007).

The first important point to make is that infrastructures matter. They are not just neutral substrates that support other practices. Instead, they shape those practices; they exert agency over everything from how we communicate to how bodies move: "As physical forms they shape the nature of a network, the speed and direction of its movement, its temporalities, and its vulnerability to breakdown" (Larkin, 2013, p. 328). And as Graham and Marvin (2001) argued in their work on urbanity, social biases are often built into infrastructures that can then reify moral choices in ways that often go unnoticed because of a second major point about infrastructure: infrastructures are often "by definition invisible" and only "become visible upon breakdown" (Star, 1999, p. 380). They are typically designed not to be noticed. For example, Internet infrastructure is quite literally buried in the ground; many forms of urban infrastructure are either buried or built outside city limits.

Invisibility is complicated by a third key point about infrastructure: As Star and Ruhleder (1996) argue, infrastructures are relational. In other words, what might be one person's infrastructure may be a hypervisible piece of another person's day-to-day life. For engineers who work on roads, the road is not a substrate to support other behaviors; the road is their main job. Standards are a prime example of the relationality of infrastructure. Obviously, for people who create standards, these documents are a major part of their job. The standards seemingly disappear, on the other hand, when their guidelines are built into material objects and rendered invisible to end users. And related to relationality, one of my major arguments in this article is that technical standards show how writing can become an infrastructure upon which other infrastructures are built. Take the Internet as an example. The Internet is enabled by layers upon layers of material infrastructure, including cables, modems, and so forth. Those material infrastructures are built upon and shaped by international standards documents, and as such, the documents become a discursive infrastructure for larger material infrastructures. As Susan Leigh Star (2000) argued, "It's infrastructure all the way down" (p. 1).

Those three key points—infrastructure has agency, infrastructure is often invisible, and infrastructure is relational—have shaped much of infrastructure studies. In particular, those points have shaped the field's focus on an object of study (infrastructures of all kinds) and a loosely defined methodological approach based upon what Bowker (1994) called an "infrastructural inversion" (p. 10). An infrastructural inversion is basically a figure/ground switch that echoes some of Lanham's (1992) work on the at/through oscillations of electronic texts and involves bringing infrastructure to the forefront of analysis. This article performs a similar type of inversion on a standards document to see how often invisible texts help shape the objects with which we later interact.

The study of infrastructure can add to multiple conversations occurring within writing studies. For instance, standards (and most other texts) are a "soft infrastructure"—defined as "the previously hidden or background activities that made the system possible" (Sandvig, 2013, p. 92)—that are built into material objects in often invisible ways, and they are inherently relational. Relatedly, most discussions of the concept of infrastructure in writing studies also refer more to the "soft" infrastructures that involve people rather than material. For example, Hart-Davidson et al. (2007) examined different levels of social infrastructure that shaped content management in nonprofit organizations. Grabill (2010) used the term "infrastructure" to examine how writing programs work as infrastructure to support university programs and community outreach while also relying on various levels of infrastructure, including staff, faculty, students, and communication technology (hence the relationality of infrastructure). And Vee (2013) adopted the term "infrastructure" to better understand how "writing gradually worked its way into government and social infrastructures" (p. 59).

An embrace of infrastructure studies can also link writing studies to the "hard" discussions occurring in relation to material rhetoric, specifically the agency of nonhuman actors (Barnett & Boyle, 2016). The standards may be "soft" in contrast to the "hard" infrastructures that include material systems such as roadways or Internet cable, but their softness is then concretized and made hard as their instructions are built into material objects. The text I analyzed in this article plays a dual infrastructural role in terms of material rhetoric: The writing has agency that shapes later development, and that agency is codified into the everyday material objects that themselves are rhetorical.

The work from writing studies that examines infrastructures—whether social or material—has been valuable for theorizing different levels of either hardware, software, or social organization that are required to enact specific types of writing, but there is still work to do to build further ties between writing and infrastructure. After all, infrastructures are key to written communication. Letters do not arrive without transportation infrastructure; social media posts do not spread without networked infrastructure. But written communication is also key to infrastructure, in part through the instances of standardization examined in the previous section. However, the role writing plays as infrastructure is mostly undertheorized with the exception of work by Read (2019). Similar to the analysis I present in this article, Read uses empirical data to develop an infrastructural theory of writing. Drawing on Susan Leigh Star's (1999) eight elements of infrastructure, she specifically builds a four-part framework to understand the specific role writing plays in supporting and shaping broader practices. These parts include

1. *Inclusiveness*: A broad scope for what counts as writing
2. *Relationally Defined*: A focus on what writing does for something or someone (incorporates rhetorical genre theory)
3. *Alliance Brokering*: Writing mediates essential alliances
4. *Mission Critical*: Writing is essential to the operations of an organization. (p. 14)

This article expands upon Read's work by analyzing a specific type of important infrastructural document—technical standards—and adding a fifth element to her framework that I argue is an essential piece of infrastructural writing: embeddedness. In other words, documents such as standards become infrastructure when their guidelines become embedded inside objects and are rendered invisible to people who actually use those objects. This study makes that mundane yet essential writing visible in a novel way that differs from previous analyses: through the textual analysis of a specific standardization document. Read's recent study of writing as infrastructure was ethnographic and analyzed how multiple genres of documents worked as infrastructure at a supercomputer site. Her research, however, did not include explicit discussion of how the content of specific documents shaped that work. Her work also did not include detailed analysis of the texts as infrastructure but rather included ethnographic data on the work the texts did. Consequently, this article builds upon and seeks to extend Read's analysis in three ways:

1. Theorizing standards as discursive infrastructure
2. Providing textual, empirical support for Read's work to establish writing as infrastructure
3. Building a more comprehensive theory of infrastructural writing that will help writing studies researchers identity infrastructural documents and better understand how writing becomes infrastructure

## Methods

### The Data (the TDS)

The data for this study came from Version 1.9 of the Tag Data Standard (TDS), which is the main standard that governs the Electronic Product Code (EPC) used on RFID tags (Frith, in press). The EPC is a next-generation version of the data standards used on barcodes,[2] and the original coining of the term "Internet of Things" referred to using something like the EPC paired with RFID tags to identify items in the global supply chain (Ashton, 2009).[3] TDS remains one of the major standards of the Internet of Things, and a possible replacement someday for the data standards—the Universal Product Code (UPC) and European Article Number (EAN)—produced in the 1970s that are still used for barcodes.

I chose the TDS as the dataset for this project for multiple reasons. For one, the standard is consequential, and research has shown that multiple retailers have identified the creation of an industry standard as the reason they finally adopted RFID technology (Beck, 2018). Second, the TDS is published by GS1 and publicly available on the GS1 website (GS1, 2014). GS1 is a major international standards organization that has a presence in over 100 countries and manages over 30 standards related to identification data. Finally, the TDS is a comprehensive standard that works as a rich textual data source. Version 1.9 of the TDS is 126 pages in total with another 74 pages of appendices, though the appendices are not included as part of this dataset because they are not the main body of the TDS. The 126 pages are split into 18 sections with each of those sections split into subsections.

### Method of Analysis

To code the TDS, I used the grounded theory approach first described by Glaser and Strauss (1967). I used grounded theory because it is an inductive approach in which researchers approach a dataset with as few theoretical preconceptions as possible (Charmaz, 2006). I adopted a more inductive approach because standards have not been particularly theorized within writing studies, so there were no existing "top-down" models I could apply to the data. Rather, I wanted to begin to build a deeper understanding of what these documents include. Consequently, I did not approach the dataset with a plan to use existing linguistic or rhetorical models to understand the data. I specifically set out the explore the following question: "What rhetorical work does this standard do to support and shape the development of the Electronic Product Code?" Obviously, a full inductive analysis with no preconceptions is almost impossible, and I was familiar with Star and others' work on standards and infrastructures. However, I did not apply any kind of preexisting model to the data and coded the data as inductively as possible to see what emerged from the analysis. In addition, while I return to Read's framework infrastructural writing in the discussion section, her four elements did not influence the analysis. Rather, the analysis reports upon the categories that emerged from the data, which provides a different, yet still complementary, perspective on the infrastructural functions of writing than Read. Ideally, future research could use a combination of our frameworks and categorizations to more deductively examine different types of texts in terms of infrastructural elements.

I used NVivo qualitative data analysis software to code the data. My main goal was to group the data using codes and then to refine the codes into categories that could help me generate an initial theory of the work the TDS does to support EPC deployments. The first step of the process involved open coding, which involves coding all of the text in the document and making detailed notes about ways pieces of text are related (Charmaz, 2006; Glaser & Strauss, 1967). After the first run through the data, I then engaged in "constant comparison," which involves multiple iterations of data analysis to more clearly define and condense my categories (Huberman & Miles, 1994). In this step, I transformed the dataset from a sprawling 126-page document into a dataset that was divided into discrete categories to make the data understandable for the purpose of analysis and prose exposition. To aid that process, I engaged in an extensive memoing process that identified links among categories and enabled me to write out descriptions and examples of what each category contained and how each category was different from other categories. I continued this process through seven iterations of coding the complete data set until I reached an adequate level of understanding and was confident in my ability to explain my categorization to another coder. Throughout these iterations, I refined the category definitions and merged some categories when I noticed repeated overlap and added additional detail to differentiate closely related categories. For example, one category includes "explanations," and another includes "instructions." At one point, these were part of one larger instructional category, but through the multiple iterations I realized they were serving different rhetorical purposes. The explanatory content focused on examples and use cases rather that did have some instructional elements but were not primarily procedural. Throughout the coding iterations, I added extensive description to the category to explain these differences with the goal of being able to replicate my thought process in coordination with a second coder.

I focused on the distinct types of content present in the document so I could better understand how the text worked to support the deployment of the EPC. As Smagorinsky (2008) states, any qualitative coding involves a researcher approaching a text with a goal in mind. I was interested in creating an inductive categorization of how the standard document worked as a text. In other words, I started by asking questions like: What types of content did the text contain? How did it function as both a standalone document and one document amongst many related to the topic? I was focused on the rhetorical work the document was designed to accomplish, particularly how the text functioned in a way that was both relational (drawing from infrastructure studies) and included content that shaped its final object of focus (the EPC). I did not create the codes to achieve an "objective" analysis of data, and I make no claims that another researcher would develop the same categories. Rather, the categories below "explicate the stance and interpretive approach that the researcher brings to the data" (Smagorinsky, 2008, p. 401), and I refined the categories so that they were explicable and understandable to a second coder.

I then began the interrater reliability portion of the process. While interrater reliability is not always necessary in grounded theory approaches, it can lend authority to the data analysis because it shows an outside coder was able to apply the defined categories accurately. To achieve interrater reliability, I began by giving my research assistant descriptions of the categories that emerged from my data. We then went through a training period in which she watched as I coded a small portion of data while explaining my choices to her, and she asked questions. She then coded small portions of data and explained her thought process. Once she felt she understood my categorization, she began the coding process herself. She coded the entire dataset using my categories, and I then compared her coding to mine using the Cohen's kappa coefficient, which is a widely accepted statistic for measuring coding agreement that is superior to simple percentage agreement. The final Cohen's kappa was .81, which, according to Fleiss (1981), falls in the "excellent" range of agreement. With the high Cohen's kappa, I felt comfortable the categories were well defined and accurately coded.

## Data Analysis

Through the multiple iterations of coding, categories emerged that represented the rhetorical goals of the TDS I identified. I created the six categories to correspond to unique types of content I identified in my analysis, including mentions of audience, intertextual references, examples and explanation, instructional content, and definitional work. While there is some conceptual overlap amongst categories, I used a mutually exclusive coding scheme, so each passage could only receive one code. I also include the number of references coded in each category, though references could be of different length and should not be taken as a straightforward representation of how much of the TDS was comprised of each category. Table 1 shows the six categories and includes a short description of how I defined them in my memoing process.

## *Explicit Mention of Audience (One Reference)*

Infrastructures are relational in the sense that one person's infrastructure can be another person's primary job. Standards are a form of relational infrastructure, which was found in the data through the one explicit mention of audience:

> The target audience for this specification includes:
>
> - EPC middleware vendors
> - RFID tag users and encoders
> - Reader vendors
> - Application developers
> - System integrators

A brief discussion of audience is expected, but it shows in theoretical terms the way relationality works in practice. For the people outside those audiences who interact with RFID tags, the TDS is an invisible infrastructure; someone on a retail floor or a distribution center likely does not know the TDS exists. But for those five bullets above, the TDS is a topic they are highly aware of rather than a discursive infrastructure that fades into the background. Certain documents then are relational in much the same way a fiber optic cable is more primary object than infrastructure for the person laying it.

## *Version Control (14 References)*

Many infrastructures end up being viewed as static, as a given waiting to be accessed. As discussed above, they are often taken for granted except in moments of breakdown. But infrastructures are fluid and always in a state of becoming. They decay and require maintenance; they shift as new practices emerge. They are not just built once and ignored. The analysis of the text of the TDS shows how the discursive infrastructure of standardization fits within the understanding of infrastructure as always indeterminate. In fact, a consequential piece of the text involved version control to mark the TDS as a living document that has changed over time. The first instances were in the front matter and covered the following topics:

**Table 1.** Emergent Categories and Descriptions From the TDS.

| Name of category | Description of category |
|---|---|
| Explicit mentions of audience | Any piece of text that explains who the target audience is for the TDS or a specific piece of the TDS. |
| Version control | Any piece of text that explicitly recognizes the TDS as a living document by referencing changes made from past versions or specific design choices made in consideration of future versions of the document. |
| Intertextuality | References to other documents that guide the reader to sources outside the TDS as text. These references can be required or suggested reading. They do not take consistent form in the text, so they may include formal citations or offhand mentions to other standards and documents. |
| Examples and explanations | Detailed textual displays of what something should look like. The example parts might include lines of code or data strings meant to be emulated by the reader. Explanations can include detailed descriptions of what RFID deployments might look like. This category is different from procedures because it does not include any procedural material. |
| Procedures and instructions | Textual chunks that are explicitly instructional in nature. Text in this category should only include material that tells the reader to do something in sequential order. The difference between this category and examples and explanation can be subtle, but that category does different rhetorical work of explaining rather than instructing explicitly how to do something. |
| Definitional work | Blocks of text meant to define processes or terms so that people from different industries would be able to draw from a common vocabulary/understanding of uses. This category includes three types of content: 1. Explicit definition of terms, 2. Uses and applications, and 3. Component testing.<br>1. Explicit definition of terms is straightforward and defines acronyms and other technical terms. These definitions are commonly, though not always, made clear in the text.<br>2. Uses and applications explains how parts of the TDS could be used in real-world deployments.<br>3. Component testing features definitional work that explains what something **must** include to meet the standard. These strands of text tell the reader what they must do to meet the definition of a process found in the standard. |

- The publication date
- The version of the standard (1.9)
- The mostly minor differences from Versions 1.6, 1.7, and 1.8
- A link for the reader to check whether or not this is the most recent version of the document

Later in the document, a few other instances of the category appeared, mostly in discussions of backward compatibility and data capacities reserved for future use. These examples mark the standard as a future-facing document, just as material infrastructure may be built modularly so that it can be added to later. For example, by reserving data space in Version 1.9, later versions are free to expand header length and open up new numbering combinations:

> For future expansion purpose, a header value of 11111111 is defined, to indicate that longer header beyond 8 bits is used; this provides for future expansion so that more than 256 header values may be accommodated by using longer headers.

The TDS features explicit engagement with the modular changes to the standard over time (the TDS 1.9 is more than 50 pages longer than the first version published in the mid-2000s) and features a clear marking of spaces the standard will be changed in future versions. Here the rhetorical elements of version control serve a crucial infrastructural function: The data strings published in older version may not line up with the current discursive infrastructure of the TDS.

### *Intertextuality (58 References)*

The TDS is a major standard used in retail and logistics and a key discursive infrastructure in the growing Internet of Things. The data analysis revealed, however, that it is likely impossible to fully understand the TDS without engaging with a host of other standards. The TDS referenced over 30 standards, ranging from standards about how RFID tags communicate with readers to standards about the data structures required by the U.S. Department of Defense. The two references below show different ways intertextuality was acknowledged within the TDS:

> The details of what information to encode into these fields is explained in a document titled "United States Department of Defense Supplier's Passive RFID Information Guide" that can be obtained at the United States Department of Defense's web site (http://www.dodrfid.org/supplierguide.htm).

> The GS1 General Specifications reserve codes beginning with either 04 or 0001 through 0007 for company internal numbering (See [GS1GS14.0], Sections 2.1.6.2 and 2.1.6.3.).

The analysis showed that the TDS essentially could not exist without the intertextual references to other standards. In many of the instances of this category, the text builds upon already existing, widely adopted standards such as many of the ISO standards or the GS1 General Specifications. The TDS is a pseudo-substrate upon which much RFID tagging is shaped, but the TDS itself relies upon existing discursive infrastructures to operate. To paraphrase an earlier quote, it's [discursive] infrastructure all the way down.

## *Examples and Explanations (84 References)*

The TDS is a varied document that combines multiple types of content. One of the major types of content provides explicit examples of how elements should be implemented or what specific data formats should look like, as in the text below:

> In both URI forms, control field name-value pairs may occur following the urn:epc:tag: or urn:epc:raw:, as illustrated below: urn:epc:tag:[att=x01][xpc=x0004]:sgtin-96:3.0614141.112345.400 urn:epc:raw:[att=x01][xpc=x0004]:96.x012345689ABCDEF01234567

At other points, the explanations went further and explicitly detailed what each piece of the data format corresponded to:

> - urn:epc:tag:[att=x01]:sgtin-96:3.0614141.112345.400
>
> This is a tag with an SGTIN EPC, filter bits = 3, the hazardous material attribute bit set to one, no user memory (user memory indicator = 0), and not recommissioned (extended PC = 0). This URI might be specified by an application wishing to commission a tag with the hazardous material bit set to one and the filter bits and EPC as shown.

The large blocks of text devoted to examples and explanations suggest that the TDS operates in part as both a teaching manual and a reference guide. The examples of data formats are a reference that can be returned to later. The explanation sections encouraged a deeper level of engagement that understands the choices rather than just replicates them. Importantly, many of the examples included long blocks of code and data structures, showing how discursive infrastructures may extend beyond typical textual forms and will involve an expanded definition of what counts as writing.

In addition, the explanations and teaching cases sometimes extended beyond straightforward explanations of data. As an example, the document included explanations of hypothetical deployments of RFID tags for a range of uses. The paragraph below is one example:

> In this example, there is a storage room in a hospital that holds radioactive samples, among other things. The hospital safety officer needs to track what things have been in the storage room and for how long, in order to ensure that exposure is kept within acceptable limits. Each physical object that might enter the storage room is given a unique Electronic Product Code, which is encoded onto an RFID Tag affixed to the object. An RFID reader positioned at the storage room door generates visibility data as objects enter and exit the room, as illustrated below.

The three text references shared in this section are different, but they ultimately serve a similar purpose: to explain and provide examples. The ability to encourage a deeper understanding of EPC deployment represents how the inner-workings of RFID deployment are learned, and a familiarity with the TDS becomes a key part of that broader community of RFID developers. The examples provided in the TDS may eventually be internalized by readers and once again fade into the background of how the EPC is deployed.

## *Procedures and Instructions (145 References)*

The bulk of content found in the TDS focused on instructional material. The forms instructional content took throughout the document differed depending on section, with some sections clearly demarcating instructions with words like “procedure”:

> Procedure:
>
> 1. Bits b0 . . . b7 should match the value 11100010. If not, stop: this TID bank contents does not contain an XTID as specified herein.

Other sections placed potentially important instructional content inside longer paragraphs:

> While the internal structure of the EPC may be exploited for filtering, selection, and distribution as illustrated above, it is essential that the EPC URI be used in its entirety when used as a unique identifier.

Those two examples are just a few of the forms instructional content took, and that inconsistency likely relates to an earlier point about how infrastructure is always evolving. Over the various versions, the TDS added more than 50 pages, 11 sections, and 8 appendices, and that growth is reflected in the data in the inconsistencies in procedural content. Just as a material infrastructure may be added to in a piecemeal, less than perfect, fashion, so are discursive infrastructures that grow over time.

Regardless of some inconsistencies, the overall focus on instruction raises questions about the infrastructural nature of writing more generally. Standards are a base upon which material infrastructures are built. Material infrastructures are an assemblage of parts that come together to form a seemingly unified whole. For those pieces to fit, many of them must be standardized. The roads all must be the same width, the modems must use similar frequencies, the tags of different products flowing through a distribution center must follow the same format. Larger infrastructures are the result of the infrastructural work of standardization, and in particular, the result of standards' ability to instruct people how to design objects or shape practices so they conform with the standards and can work at multiple sites. Take the example below:

> Procedure:
>
> 1. Starting with the EPC Pure Identity URI, replace the prefix urn:epc:id: with urn:epc:tag:.
>
> 2. Replace the EPC scheme name with the selected EPC binary coding scheme name. For example, replace sgtin with sgtin-96 or sgtin-198.
>
> 3. If the selected binary coding scheme includes a filter value, insert the filter value as a single decimal digit following the rightmost colon (":") character of the URI, followed by a dot (".") character.

Behind that technical language is a fairly straightforward directive: design the data format in this way or do not enter into the network of standardized objects moving through the world. Just as materials have to be designed to work with the infrastructure they use (e.g., the width of a truck or Internet routing protocols), so must objects be designed to work with and follow the instructional content within the standards they follow.

## *Definitional Work (198 References)*

Infrastructure is learned by the community that engages with it, and only after it is learned does it move from a primary object of focus to a more ready to hand infrastructure. For example, when a university introduces a new type of grant routing infrastructure, it is a primary object of focus before it becomes ready to hand and supports other operations (assuming that ever happens). The TDS faces the same issues in its role as a discursive infrastructure to support the global supply chain more generally and RFID deployment more specifically. Namely, one of the major roles of the TDS was to provide definitional work to enroll the audience into a broader community of practice, or in other terms, enable audiences across industries to essentially speak the same language.

The TDS provided three primary forms of definitional work: (a) explicit definition of terms, (b) uses and applications, and (c) component testing. The first type of definitional work is the most straightforward, with clear definitions of terms such as "filter value," "Attribute Bit," and so on. The second type focused on how specific pieces of the TDS could be implemented in actual practice:

> The EPC Tag URI begins with urn:epc:tag:, and is used when the EPC memory bank contains a valid EPC. EPC Tag URIs resemble Pure Identity EPC URIs, but with added control information.

Finally, as a next step beyond application, the TDS also defines processes by providing testing mechanisms to validate different parts of EPC deployment. Much of the TDS focuses on various tests to make sure all component pieces are constructed properly. Below is a small example of a longer validity test:

> Validity Test: The input must satisfy the following:
>
> - The three most significant bits of the input bit string, considered as a binary integer, must match one of the values specified in the "partition value" column of the partition table.

The explicit focus on implementation, first in the form of a knowledge base through definition, then in descriptions of direct application, and then in methods of how to test those applications, reflects how the TDS works simultaneously as a pedagogical tool and an infrastructural document. The TDS as writing standardizes definitions and applications to broker alliances across industries and organizations and becomes a critical infrastructure in the global supply chain more generally. For products to flow freely, be identified through RFID, have records uploaded to databases, and so on, the people implementing these systems must agree upon basic definitions and must follow guidelines for applications. If that agreement does not happen, the larger mobility infrastructure crumbles. For example, if six suppliers ship to a larger distributer through a distribution center, all six must follow the same transmission protocols and data formats. If they do not align the materiality of their RFID tagging with the text of the TDS, the system becomes inoperable. The interoperability across a range of suppliers may happen fairly seamlessly when everything works, but that seamlessness hides the role standards play as discursive infrastructure.

## Discussion

Many types of writing are crucial to organizational functions but remain mostly invisible, and while my focus on texts as infrastructure may be unique, that focus builds on existing writing studies research that focuses on often hidden texts—including medical records (Schryer, 1993) and notes and lists as part of engineering projects (Winsor, 1994)—that mostly remain unnoticed. The focus on the invisible/minor is important because as Read (2019) points out, for the most part "these essential documents remain unknown" both to writing scholars and the general public (p. 263). And few examples of writing remain more unknown than standards documents. One can safely assume that no one could list all the ways their lives are shaped by standards documents. Everything from a bridge to a microchip in my dogs' backs to a temperature-monitoring system for food is shaped by standards that are mostly only visible to subject matter experts. And that invisibility is one of the keys to developing an infrastructural theory of writing: namely, *many objects we interact with can be thought of as a collection of oft-ignored documents in physical form.*

As the findings suggest, the invisibility of standards is of course not complete. The text of the standard is a day-to-day topic for the specific audiences identified in the TDS and not a hidden infrastructure, which is why infrastructural writing must be relationally defined. Or as Star (1999) puts it, "For a railroad engineer, the rails are not infrastructure but topic" (p. 380). Many other forms of professional writing—even broadly defined to include code (Brock, 2019; Vee, 2013)—are hypervisible to small audiences but then get built into material objects, software interfaces, physical procedures, and so on and then seemingly disappear.

In many cases, these documents become infrastructures for other infrastructures. This article shows how the TDS works as an infrastructure that supports and shapes infrastructures of identification in the global supply chain. Regardless, the core concept remains the same and shows how infrastructures are fractured, layered, and much more complex than the common use of the term implies (Dourish & Bell, 2007). And to complicate the relationality even more, while standards like the TDS are infrastructures for larger infrastructures, they could not be created without infrastructural support, whether that support involves the “soft” infrastructures of standards organizations or the “hard” infrastructures of computing and networking that allows standards to be created and distributed. And in terms of intertextuality analyzed above, the standard itself was supported by other standards doing infrastructural work. In infrastructural terms, the text of the TDS was “built upon an installed base” (Star & Ruhleder, 1996, p. 113), meaning infrastructures are substrates that support other substrates and are complex and multifaceted. Infrastructures are everywhere. Whether discursive or material, they are theoretically important because they are a base upon which further actions occur, and they do not just support those actions; they shape them.

Writing studies has much to gain from adapting literature from and adding to infrastructure studies. This article has shown how through an analysis of standards as infrastructure, but the approach could benefit the field more broadly. For one, infrastructure studies positions infrastructures as in a constant state of becoming, whether that becoming involves improvement, maintenance, or decay. The data discussed above show how that becoming impacts standardization because the TDS is a living document that has gone through multiple versions. These versions do not involve full rewrites; rather, they were added to section-by-section over more than a decade, reflecting Star’s (1999) observation that infrastructures are “fixed in modular increments” (p. 382). And once again, while this analysis focused on standards as evolving, modularly fixed pieces of infrastructure, the same concept can be applied to other types of documents. After all, infrastructures decay if they are not maintained. The same is true for discursive infrastructures. Companies’ policy documents become outdated, content management plans become unwieldy, documentation may not keep up with code changes, and so forth. Discursive infrastructures, whether standards or not, must be maintained or else their power weakens. Just as a road will eventually crumble without maintenance, discursive infrastructure will become less and less functional without updates and care.

Relationality, modularity, and relative invisibility are elements of most infrastructures. They can be just as easily applied to a road system as they can be applied to the technical documents that prop up and shape that road system. But Read’s (2019) work on specificities of writing as infrastructure provides a framework we can use to look at and evaluate texts’ infrastructural functions. While I did not use her framework as an analytical tool for coding my data, it can nonetheless be adapted to fit within the categories presented above:

1. *Inclusiveness*: An infrastructural theory of writing involves a broad sense of what counts as writing, including code, auto-generated data reports, and so on. Understanding the infrastructural role of standards often requires that broad scope, as seen in the "Examples" section of the TDS that included pages of code as instruction.
2. *Relationally Defined*: Standards are relational documents. They are a primary focus for defined audiences (defined explicitly in the front-matter of the TDS) but are mostly ignored discursive infrastructures for people outside those specific audiences. The TDS makes explicit whom the documents are for, which is key to a relational understanding of writing as infrastructure and links relationality with the core importance of audience in writing studies (Luzón, 2013). The same document (regardless of type) may be the primary object of focus for certain people; for others, it becomes a discursive infrastructure that supports later behaviors/materialities.
3. *Alliance Brokering*: Standards mediate alliances. Often for a larger infrastructure to work, its component parts must be standardized and interoperable. In other words, objects must align with the discursive infrastructure for a system to appear seamless. The alliances were brokered in the TDS through the instructional and definitional content that encouraged engineers to align design choices and data formats. This type of infrastructural brokering is in no way exclusive to standards. Proposals often have to ensure interoperability, documents have to cite laws and regulations, and so forth. One of the key aspects of writing often involves brokering alliances between multiple audiences.
4. *Mission Critical*: Many organizations require partners to follow standards. For example, the Department of Defense requires suppliers to align with the TDS. In those cases (and many others) the standard becomes a crucial document that is necessary for the proper functioning of a larger system. Once again, the standard in this case illustrates a larger point about infrastructural writing that can be applied to other forms of writing. For example, Dorothy Winsor's (1988) work showed how miscommunications may have contributed to the Challenger disaster. Those documents were mission critical, and they failed. If the mission had succeeded, the documents would have been no less critical; however, they would have faded into the background and never received attention, which is the fate of many infrastructures when they work as they should.

Read's framework can be adapted in future work, just as my analysis of the rhetorical work standards do as infrastructure can be adapted to understand other types of writing or analyze other examples of standards documents. In addition, my analysis shows that Read's framework for infrastructural writing can also be built upon by focusing on how the writing becomes invisibly embedded in social practices and material objects, something arguably missing from her four-part framework. As a growing number of rhetoricians have argued, the field should pay more attention to the persuasive agency of material objects (Barnett & Boyle, 2016). A theory of writing as infrastructure can link these forms of material rhetoric to writing studies by examining how writing is rendered invisible but concretized in later practices and objects. People interacting with an RFID tag do not need to know the TDS exists, but the materiality of the tag is shaped by the categories examined above, particularly the focus on examples of data structures and tag requirements. Consequently, based upon my analysis, I propose a fifth element to the infrastructural theory of writing first developed by Read:

5. *Embeddedness.* For writing to be infrastructural, it must become embedded in later practices or material objects. The documents must fall away for end users and become figuratively buried inside objects. Some of the categories of the TDS, for example, are infrastructural in the sense that they become embedded in the shape and inner workings of RFID tags. But that embeddedness is not exclusive to standards. Software documentation can be infrastructural when it then shapes later code. Content policies can be infrastructural when they become embedded in cross-platform content strategy and shape the content people interact with across platforms.

I argue that the data analyzed in this study supports the value of adding a fifth part to a theory of infrastructural writing. After all, infrastructures shape practices and often drop out of sight, while also becoming more integrated into core parts of a system. Sewer lines are literally buried in the ground; a whole host of standards and other planning documents are figuratively buried in those sewer lines. Embeddedness as a concept lets us further examine how writing gets built into objects and erases itself as the objects go out into the world and work (or do not work) as intended.

With Read's broader framework and my textual analysis of the infrastructural role a specific text plays in the shaping of the material world, we have the initial steps in developing an infrastructural theory of writing. Many infrastructural documents will be technical, mundane, and buried beneath flashier exteriors where people actually interface with the systems the documents describe; they will require researchers to follow Star's (1999) "call to study boring things" (p. 377). But these seemingly boring things are consequential. They are a necessary piece of how our world works, and the systems we rely upon crumble without them.

## Conclusion and Future Research

Infrastructures are often designed not to be noticed. They are buried in the ground, built on the outskirts of urban areas, and designed to blend into the environment. They become more visible when they stop working seamlessly and stop supporting the behaviors for which they are built. The same is true of a range of documents that work as infrastructure. When everything works seamlessly people forget how important the documents can be. It is in moments of breakdown and failure when the foreground/background relationship flips and infrastructure becomes the focus of attention (Bowker, 1994; Bowker & Star, 1999). The discursive infrastructures of standards work in the same way. For example, people may not be aware of building code standards until they find their electricity is wired incorrectly. They may be unaware of addresses related to IP addresses until they cannot access the Internet because of an IP address conflict. As Busch (2011) suggests, standards "determine what shall count. Those people and things that pass the tests or make the grade are drawn into various networks" (p. 12). The same standard that may go mostly unnoticed may become visible at worksites when an object tries and fails to enter into the network of standardized objects.

This article has used an analysis of standards to further develop an infrastructural theory of writing first proposed by Read (2019). Standards are an example of how writing can be a substrate upon which material objects are built. The words in the documents quite literally shape many parts of the physical world. And standards are not alone as examples of writing that serves an infrastructural function. The type of inductive research performed in this study could be done on other types of "hidden" writing, such as progress reports, proposals, and so on. Or researchers could apply an existing analytical framework derived from mine and Read's work to apply to other forms of writing. Regardless, future research can provide similar analyses of other types of documents—including other standards, unnoticed organizational documents, regulatory reports, or even types of writing such as data printouts produced automatically that are not produced by humans—that may go unnoticed by most but provide infrastructural support for a broad range of practices.

In sum, literature from infrastructure studies has much to add to writing studies research, just as writing studies research has much to add to infrastructure studies. This article, along with Read's recent work, is an initial step in strengthening those links. Future research has ample opportunity to further examine the roles different types of writing (broadly defined) serve as agential substrates that are codified into the design of the physical world.


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## Notes

1. IpV4 and IpV6 are the standards that dictate the structure of IP addresses used to identify devices connected to the Internet. IpV6 offers an expanded range of numbers and is an important standard for the growth of the Internet of Things.
2. The Electronic Product Code is a data standard that is expansive enough to uniquely identify every object on earth. The code is included on RFID tags, so whenever a tag is attached to an object, RFID systems are able to uniquely identify that object with a granularity that is not possible with barcodes (for a detailed discussion of the Electronic Product Code, see Frith, 2019, chap. 2).
3. The Internet of Things refers to objects that can communicate with each other and with the Internet more broadly. Examples include smart thermostats, contemporary cars, and so on. But the Internet of Things also includes objects that might not have an Internet connection but can communicate wirelessly in other ways. As Weber and Wong (2017) argue, "the 'things' that the Internet of Things will connect subsume and go beyond devices with computational capabilities, to include any and potentially all devices that have some ability to sense their environment or generate data about their interactions with other devices and/or people."

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