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Citation Behavior of Aerospace Engineering Faculty

Jane Stephens *, David E. Hubbard, Carmelita Pickett, Rusty Kimball

University Libraries, Texas A&M University, 5000 TAMU, College Station, TX 77843, USA

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ABSTRACT

Citation analyses provide valuable insights into the usage of library collections and assist in collection management decision-making; however, there are few engineering citation analyses of faculty publications. This study addresses that gap through an analysis of 3488 citations from aerospace engineering faculty publications by source, format, age, and subject. Local holdings were assessed based on the 80/20 rule and journal titles ranked. In addition to supporting citation patterns identified in previous citation analyses, this study revealed some novel relationships involving formats and subjects. The results of this study have implications for collection management.

INTRODUCTION

As Science, Technology, Engineering, and Mathematics (STEM) associations and national advisory groups issue reports outlining strategies to improve STEM education (Committee on Prospering in the Global Economy of the 21st Century, 2007; National Academy of Engineering, 2005; President's Council of Advisors on Science and Technology, 2012), it is important to embed librarians in university and curriculum committees, organize discipline-based research teams, and develop collection development policy statements. These activities should not be used in isolation; collectively they inform librarians' understanding of national engineering pedagogy, which in turn inform library acquisitions programs, influence collection development practices, and document the interdisciplinary nature of STEM disciplines.

Founded in 1876 as a land grant college, Texas A&M University (TAMU) was one of the first universities to become a land, sea, and space grant institution. TAMU is the flagship university for the Texas A&M University System (Texas A&M University, 2013c). The University supports approximately 120 undergraduate and 240 graduate degree programs in 10 colleges (Texas A&M University, 2013a). The College of Engineering, with approximately 350 faculty members, 11,000 students, and 22 programs, is the largest college on the TAMU College Station campus (Texas A&M University Engineering Communications, 2013). Not surprisingly, TAMU Libraries has made significant investments in STEM publications and resources. As engineering scholarship and degree programs evolve, it is critical that TAMU Libraries assess and monitor how well the libraries' collections support these developments.

The Department of Aerospace Engineering is 1 of 12 departments in the engineering college; it has approximately 35 faculty, 683 undergraduate, and 135 graduate students (Texas A&M University Engineering Communications, 2013; Texas A&M University, 2013b). The department offers Bachelor of Science, Master of Science, Master of Engineering, and Doctor of Philosophy degrees. Students may also earn certificates in business management, energy engineering, polymer specialty, and several other areas.

The TAMU Aerospace Engineering faculty is divided into three divisions: Aerodynamics & Propulsion, Dynamics & Control, and Materials & Structures. Four aerospace faculty members also hold appointments in an interdisciplinary Materials Science & Engineering program at TAMU. Three faculty members in Mechanical Engineering, one in Physics and Astronomy, and one in Mathematics hold joint appointments in Aerospace Engineering.

The department's research centers and laboratories include: Space Engineering Research Center, Memory Alloy Research and Technology, Materials and Structures Laboratory, and Flight Mechanics Laboratory. The aerospace faculty has five areas of research focus: Aerospace Propulsion and Energy Systems, Autonomous Unmanned Vehicle Systems, Controlled Intelligent Materials and Structures, Hypersonic Vehicle Systems, and Space Exploration and Sensing Systems.

LITERATURE REVIEW

CITATION ANALYSIS

Citation analyses are often used to assess a library's collection, generate lists of core publications, and identify items for selection, cancelation or storage (Johnson, 2009). In a review of citation analysis

* Corresponding author. Tel.: +1 979 845 5382.
E-mail addresses: jstephens@library.tamu.edu (J. Stephens), hubbardd@library.tamu.edu (D.E. Hubbard), cpickett-k@library.tamu.edu (C. Pickett), rkimball@library.tamu.edu (R. Kimball).

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methodologies, Hoffmann and Doucette (2012) found that most citation analyses included: types of resources cited, frequency of cited journal titles, age of cited resources, and library holdings of the cited resources.

FORMATS

Many of the published citation analyses that involve engineering, specifically or as part of a larger study, focus on theses and dissertations (Bierman, 2012; Conkling, Harwell, McCallips, Nyana, & Osif, 2010; Eckel, 2009; Fransen, 2012; Kayongo & Helm, 2012; Kriz, 1978, 1984; Kushkowski, Parsons, & Wiese, 2003; Ucak & Al, 2009; Williams & Fletcher, 2006). The objectives, methodologies, and subject granularity of these studies differ, but characterization of the format types is common. There are fewer citation analyses involving engineering publications or engineering faculty research. Wilson and Tenopir (2008) conducted a local citation analysis by sampling faculty publications across five broad disciplines that included engineering. Musser and Conkling (1996) performed a citation analysis of 16 society engineering journals covering an equal number of engineering disciplines; however, the study did not provide results for each of the 16 engineering disciplines individually. In the only known citation analysis involving professional aerospace engineering researchers, Sridhar (1985) examined the publications of the Indian Space Research Organisation's Satellite Centre. Journals, conferences, and monographs were the only formats that were routinely reported and accounted for the majority of the citations. Table 1 summarizes the main formats and percentages of each for the citation studies reviewed (Bierman, 2012; Conkling et al., 2010; Eckel, 2009; Fransen, 2012; Kayongo & Helm, 2012; Kriz, 1978, 1984; Kushkowski et al., 2003; Musser & Conkling, 1996; Sridhar, 1985; Ucak & Al, 2009; Williams & Fletcher, 2006; Wilson & Tenopir, 2008).

Table 1
Citation formats of previous engineering citation studies.

Citation study	Source publication(s)	% Journals	% Conferences	% Monographs
Engineering				
Eckel (2009)	Theses[a]	29.3	12.5	20.5
Kriz (1978)	Theses[a]	33.3	–	–
Williams and Fletcher (2006)	Theses[a]	38	19	18
Kriz (1984)	Dissertations[a]	42.6	–	–
Eckel (2009)	Dissertations[a]	44.3	21.9	17.3
Bierman (2012)	Theses[a,b]	46	13	22
Fransen (2012)	Theses and dissertations[a]	48	31	10
Bierman (2012)	Theses[a,c]	50	20	15
Conkling et al. (2010)	Dissertations[a,b]	52	19	18
Musser and Conkling (1996)	Journal articles[a]	53	19	12
Conkling et al. (2010)	Dissertations[a,c]	54	24	12
Kushkowski et al. (2003)	Theses and dissertations[d]	59	11[e]	22[e]
Ucak and Al (2009)	Theses and dissertations[d]	60.3	6.2	25.7
Kayongo and Helm (2012)	Dissertations[a]	64	–	14
Wilson and Tenopir (2008)	Journal articles[d]	73.9	–	15.5
Aerospace engineering				
Kriz (1978)	Theses	11.4	–	–
Kriz (1984)	Dissertations	25.6	–	–
Williams and Fletcher (2006)	Theses	31	22	22
Eckel (2009)	Theses[f]	46[e]	15[e]	19[e]
Conkling et al. (2010)	Dissertations[b]	50	18	27
Conkling et al. (2010)	Dissertations[c]	50	24	20
Eckel (2009)	Dissertations[f]	55[e]	21[e]	12[e]
Fransen (2012)	Theses and dissertations	58[e]	13[e]	14[e]
Kayongo and Helm (2012)	Dissertations[f]	59	9	22
Sridhar (1985)	Journal articles	60.6	9.7	14.4

[a] Two or more engineering disciplines including aerospace engineering.
[b] The citation analysis performed on theses or dissertations published in the 1990s.
[c] The citation analysis performed on theses or dissertations published in the 2000s.
[d] Two or more engineering disciplines excluding aerospace engineering.
[e] Values estimated from bar charts.
[f] Combined aerospace and mechanical engineering department.

80/20 RULE

The 80/20 rule is a principle used to describe scatter or dispersion in various contexts including library usage and collections (Nisonger, 2008; Trueswell, 1969). Like Bradford's law of dispersion (Bradford, 1934), the 80/20 rule describes how the majority of relevant documents within a field can be found in small number of publications (e.g., 20% of the collection accounts for 80% of usage). In a review of nine citation analyses, Nisonger (2008) concluded that the citation analyses generally adhered to the 80/20 rule, but none involved engineering. While the engineering citations analyses examined did not specifically mention the 80/20 rule, five did discuss dispersion of the cited articles among journals. In a study of engineering theses, Williams and Fletcher (2006) found that 9.6% of the journals cited accounted for half of all cited journals. Kriz (1984) found that half of all journals citations in engineering theses and dissertations came from 11% and 8.7% of journals cited, respectively. In an analysis of engineering journals, Garfield (1977) found that 10% of the journals accounted for 50.4% of the citations. Sridhar (1985) found that 11% of journals cited by space technologists accounted for 59.96% of the citations.

AGE DISPERSION

Methodologies utilized to determine and report citation age varied among the citation studies reviewed above, which makes comparisons and summarizing their results challenging. When an average citation age was reported in the engineering citation studies reviewed, it was often determined based on all formats and/or disciplines within the study (Conkling et al., 2010; Kayongo & Helm, 2012; Kushkowski et al., 2003). Some citation studies also included the oldest citation or listed age ranges for each format or collectively for all formats (Conkling et al., 2010; Eckel, 2009; Musser & Conkling, 1996; Williams & Fletcher, 2006). Eckel (2009) reported average thesis citation ages of 11.8, 9.7, and 11.9 years and average dissertation citation ages of 16.6, 9.2, and 15.7 years for journal articles, conference papers, and monographs, respectively. Fransen (2012) reported average ages of 16.1, 12.0, and 20.6 years for aerospace engineering journal articles, conference papers, and monographs, respectively. The oldest citation in Williams and Fletcher's (2006) study of aerospace engineering theses was 66 years old. In multi-institutional analysis of aerospace dissertations, Conkling et al. (2010) found citations ranged in age from 0 to 148 years during the 2000s.

SUBJECT DISPERSION

In the citation studies reviewed in this paper, only Williams and Fletcher (2006) and Fransen (2012) classified the journals cited in engineering theses and dissertations using the Library of Congress Classification. Williams and Fletcher (2006) reported the following for journals cited in the aerospace engineering theses: 77% (T-Technology), 19% (Q-Science), 2% (R-Medicine), and 2% (G-Geography/Anthropology/Recreation). In contrast to Williams and Fletcher (2006), Fransen (2012) found the following for journals cited in the aerospace engineering theses and dissertations: 64% (Q-Science), 35% (T-Technology), and 1% (Other). Fransen (2012) attributed the citing of more Science (Qs) over Technology (Ts) to a strong emphasis of fluid mechanics research at their institution. Both Fransen (2012) and Williams and Fletcher

(2006) illustrate that a substantial number of journals cited in their aerospace engineering studies are from disciplines outside of engineering.

PURPOSE AND OBJECTIVES

There are no known citation analyses of aerospace engineering faculty publications. The present study addresses this gap by focusing on faculty publications and including subject analysis of major formats cited, rather than journal citations exclusively. The objectives are to determine how well the TAMU Libraries' collection meets the needs of the faculty in the Department of Aerospace Engineering, identify gaps in the collection, and to adjust collection development policies accordingly. The research questions are:

- What types of material (formats) does the faculty cite and on which types do they rely most?
- What are the most frequently cited publications?
- What is the age (average, range) of the material cited?
- On which subjects does the Aerospace Engineering faculty rely for research and does that vary by format?

The answers to these research questions have implications for collection management and will be discussed.

METHODOLOGY

FACULTY PUBLICATIONS

Thomson Reuters' Web of Science was used to retrieve publications authored by faculty of the TAMU Department of Aerospace Engineering. The faculty publications were compiled by searching for the department name and ZIP code in the address field of the database (i.e., Aerosp* SAME 77843). The publication year range was limited to 2008 and 2009. The results were further refined to include only journal articles, proceedings, and review articles. The result set was exported to both EndNote and an Excel spreadsheet. PDFs of each faculty publication were attached to the respective record in the EndNote library for later referral as needed. Each faculty publication was assigned a unique alphanumeric code, which was also added to the spreadsheet and to respective EndNote records.

CITED PUBLICATIONS

Cited publications were retrieved from their respective faculty publication record in Web of Science and exported into a spreadsheet. The unique alphanumeric faculty publication code was also added to each citation in the spreadsheet, so that a given cited publication could be tracked back to its original faculty publication. The citations were initially divided into journal and non-journal publications. International Standard Serial Numbers (ISSNs) were added to their respective journal citations on the spreadsheet to enable easy sorting and more accurate tabulation. The most frequently cited journals, those comprising 80% of the total journal citations, were then determined.

The non-journal citations were assigned to one of eight format-based categories and sorted accordingly. Some titles and author names (particularly conference names) were normalized to ease sorting and increase accurate tabulation. The most frequently cited conferences and monographs were determined. For all nine formats, age of each cited publication (i.e., difference between date of faculty publication and the citation) was calculated to the nearest year, averaged, and recorded. Library of Congress (LC) call numbers were then added to journals, conferences, and monographs using the first LC call number listed in OCLC's WorldCat for source titles.

Local access or ownership was also determined. Items found in the TAMU Libraries' physical collection or accessible through the libraries electronic resources were included in our holdings. Since TAMU Libraries are a selective Federal Depository Library, the Libraries' electronic resources provide links to a number of U.S. government databases through the Libraries' database list (e.g., NASA Technical Reports Server and DOE Information Bridge), items found in these resources were also considered held by TAMU Libraries. Items freely available on the Internet that were not in the physical collection or accessible through the libraries electronic resources were not considered held.

RESULTS

FORMAT DISPERSION

During 2008 and 2009, TAMU's Department of Aerospace Engineering faculty authored 143 publications, which consisted of 105 journal articles and 38 conference papers. The 143 publications cited 3488 publications. The 3488 citations were categorized and sorted into nine format categories. Table 2 shows the number and percentage of the citations by publication format. Journal articles were cited most frequently (67.4%), followed by conference papers (14.7%), and then monographs (13.2%). The remaining six categories accounted for only 4.6% of the citations.

JOURNALS AND CONFERENCE PROCEEDINGS

The 2351 journal articles cited were from 410 unique journal titles. The 20 most cited journals from the study are presented in Table 3. It required 123 (or 30.0%) of the 410 journals titles to account for 80% of the citations, thus exhibiting more dispersion than the 80/20 rule would predict. The most cited journal, *Journal of Guidance, Control, and Dynamics*, was cited 142 times and the 123rd journal, the last one contributing to and satisfying the 80%, was cited four times.

The results of this study support the findings of previous studies demonstrating the importance of the conference literature to engineering researchers (Bierman, 2012; Conkling et al., 2010; Eckel, 2009; Fransen, 2012; Kayongo & Helm, 2012; Kushkowski et al., 2003; Musser & Conkling, 1996; Sridhar, 1985; Ucak & Al, 2009; Williams & Fletcher, 2006). This format proved to be the second most cited format by TAMU Aerospace Engineering faculty. Not surprisingly, the most cited conference papers were sponsored by the American Institute of Aeronautics and Astronautics (AIAA), American Astronautical Society (AAS), Institute of Electrical and Electronics Engineers (IEEE), and Society of Photo-Optical Instrumentation Engineers (SPIE). The most cited conference proceedings accounting for 50.4% of all conference proceedings cited are listed in Table 4.

AGE DISPERSION

Table 5 presents the average age and age ranges of the citations by format. Overall age of the publications ranged from zero years, for publications that were published and cited within the same year, to 149 years old for a monograph. The large standard deviations (greater

Table 2
Citations by format.

Format	Citations	% total citations
Journals	2351	67.4
Conferences	514	14.7
Monographs & monograph chapters	461	13.2
Theses & dissertations	64	1.8
Reports[a]	50	1.4
Manuals	15	0.4
Computer programs/software	6	0.2
Government documents[b]	4	0.1
Other	23	0.7
Total	3488	100.0

[a] Reports include technical reports that are U.S. government documents.
[b] Government documents exclude technical reports that are U.S. government documents.

Table 3
Most frequently cited journals ranked by citation frequency.

Rank	Journal name	Citations	% total journal citations	Cumulative % total journal citations
1	Journal of Guidance, Control, and Dynamics	142	6.0	6.0
2	Composites Science and Technology	86	3.7	9.7
3	Journal of the Mechanics and Physics of Solids	82	3.5	13.2
4	Journal of Applied Physics	56	2.4	15.6
5	Journal of Fluid Mechanics	53	2.3	17.8
6	Acta Materialia	49	2.1	19.9
7	Applied Physics Letters	46	2.0	21.9
8	AIAA Journal	41	1.7	23.6
8	Journal of Composite Materials	41	1.7	25.4
9	International Journal of Plasticity	40	1.7	27.1
9	Mechanics of Materials	40	1.7	28.8
10	Journal of the Astronautical Sciences	37	1.6	30.3
11	International Journal of Solids and Structures	35	1.5	31.8
11	Materials Science and Engineering A	35	1.5	33.3
11	Polymer	35	1.5	34.8
12	IEEE Transactions on Automatic Control	31	1.3	36.1
12	Physics of Fluids	31	1.3	37.4
13	Computer Methods in Applied Mechanics and Engineering	29	1.2	38.7
14	Celestial Mechanics and Dynamical Astronomy	28	1.2	39.9
14	Journal of Intelligent Material Systems and Structures	28	1.2	41.0
15	Physical Review Letters	27	1.1	42.2
16	Journal of Applied Mechanics	23	1.0	43.2
17	Automatica	22	0.9	44.1
17	Smart Materials and Structures	22	0.9	45.0
18	International Journal for Numerical Methods in Engineering	20	0.9	45.9
18	Journal of Engineering Materials and Technology	20	0.9	46.7
18	Modelling and Simulation in Materials Science and Engineering	20	0.9	47.6
19	Chemical Physics Letters	19	0.8	48.4
19	International Journal of Engineering Science	19	0.8	49.2
20	Physical Review B	18	0.8	50.0
20	Science	18	0.8	50.7

than the average ages in all instances) and ranges indicate considerable age dispersion among the publications cited. The average ages of the three main formats from smallest to largest were: conferences, journals, and monographs.

SUBJECT DISPERSION

Table 6 summarizes the LC classification for the journals, conferences, and monographs cited. The most salient feature of Table 6 is that the disciplines cited differ in relative intensity by format. The LC subclass with the largest number of journal citations is TA, Engineering (General), whereas the LC subclasses for conference proceedings and monographs are TL (Aeronautics, Astronautics) and QA (Mathematics), respectively.

While the largest single LC subclass for journal citations is TA, the majority of the journal citations (59.9%) are from a single LC subject division, Materials of Engineering and Construction, Mechanics of Materials (TA401–TA492). With respect to TL, the most frequently cited journal in this study is classed as Aeronautics (TL500–), but only 10 of the most frequently cited journals are classed as TL. The LC classifications for the 10 are Airplanes… Control & Stabilization Surfaces (one title), Aeronautical Engineering (three), Space Travel (three), Astrionics (one), and Rocket Propulsion (two). There are 55 journals classed as Qs, among the 123 frequently cited journals, which included 27 physics (QC), 11 mathematics (QA), 7 chemistry (QD), 5 science (Q), 4 astronomy (QB), and 1 natural history/biology (QH).

Like journals, the majority of the conferences were also classed as Ts followed by Qs (Table 6); however, the frequently cited conferences (Table 4) were mainly classed as TLs (Aeronautical Engineering), followed by TJ (Mechanical Engineering), and then TA (Engineering, General).

Most of the monographs cited are classed as QA, followed by TAs, and then QCs. Many of monographs cited are classified as general works, treatises, and textbooks. The most cited monograph (cited 11 times) is classed in QB, followed by two monographs classed in the TAs that were cited 10 times each. Among the monographs cited five or more times, three are QAs, one QC, and two are TLs.

Table 4
Most frequently cited conferences ranked by citation frequency.

Rank	Conference name	Citations	% total conference paper citations	Cumulative % total conference paper citations
1	Smart Structures & Materials (SPIE)	34	6.6	6.6
2	Spaceflight Mechanics (AAS)	33	6.4	13.0
3	American Control Conference (IEEE)	32	6.2	19.3
4	Guidance, Navigation, and Control Conference (AIAA)	32	6.2	25.5
5	Aerospace Sciences Meeting (AIAA)	30	5.8	31.3
6	Structures, Structural Dynamics and Materials (AIAA and others)	21	4.1	35.4
7	Conference on Decision & Control (IEEE)	20	3.9	39.3
8	Physique IV	18	3.5	42.8
9	Astrodynamics Conference (AAS)	11	2.1	44.9
10	ASME Mechanical Engineering Congress	10	1.9	46.9
10	International Conference on Dynamics and Control of Structures in Space	9	1.8	48.6
10	Proceedings of the Combustion Institute	9	1.8	50.4

Table 5
Citation age by format.

Format	Avg. age (yrs.)	Std. dev.	Age range (yrs.)
Journals	12.5	13.6	0–130
Conferences	8.8	10.9	0–105
Monographs & monograph chapters	20.6	21.3	0–149
Theses & dissertations	8.3	10.9	0–47
Reports[a]	16.5	17.1	0–72
Manuals	6.3	14.6	1–29
Computer programs/software	4.5	6.9	1–6
Government documents[b]	9.5	10.8	8–11
Other	21.2	40.0	0–127

[a] Reports include technical reports that are U.S. government documents.
[b] Government documents exclude technical reports that are U.S. government documents.

Table 7
TAMU libraries' holdings by format.

Format	Citations	Items held	% Held
Journals	2351	2321	99
Conferences	514	441	86
Monographs & monograph chapters	461	385	84
Theses & dissertations	64	56	88
Reports[a]	50	37	74
Manuals	15	0	0
Computer programs/software	6	0	0
Government documents[b]	4	4	100
Other	23	N/A[c]	N/A[c]

[a] Reports include technical reports that are U.S. government documents.
[b] Government documents exclude technical reports that are U.S. government documents.
[c] Since many of the "Other" were not found as cited, holdings were not computed.

The LC subclass categorization provides a succinct overview and illustrates the differences among publications cited by format; however, it should be noted that the publications cited might be drawn from very narrow areas of an LC subclass. For example, the largest single LC subclass for journal citations is TA, but the majority of the journal citations (59.9%) are from a single LC subject division, Materials of Engineering and Construction, Mechanics of Materials (TA401–TA492). Relative numbers of citations by format and LC subclass will be addressed further in the Discussion section of this paper.

TAMU LIBRARIES' HOLDINGS

TAMU Libraries' holdings of the 3488 cited publications are summarized in Table 7. The minimum expectation was to meet 80% of user needs locally based on the 80/20 rule; TAMU Libraries held over 80% for five of nine formats. The four formats that were less than 80% were: reports, manuals, computer programs/software, and other.

As outlined in the Methodology, items not in the physical collection, but accessible through the libraries' electronic resources were included in the holdings. This included 21 items accessible in government databases (e.g., NASA Technical Reports Server and DOE Information Bridge). While not included as being held in Table 7, there were 27 conference papers, 13 reports, 1 software program, and 5 manuals freely available on the Internet (i.e., not accessible through the TAMU Libraries' electronic resources). Had these freely available items on the Internet been included in Table 7, TAMU Libraries' holdings for reports and conference would have been significantly higher.

TAMU Libraries does not own any of the computer programs/software or manuals, although these specialized engineering products are not normally collected by academic libraries. The "other" format was mainly comprised of items that were not found as cited or cited as unpublished, so the number and percentage held for this format was not determined since it would not have been meaningful.

Table 6
Citations by LC classification and format.

LC class	LC subclass	Journals		Conferences		Monographs		Total	
		No.	%	No.	%	No.	%	No.	%
A	AS	2	<1	1	<1	–	–	3	<1
B	BF	1	<1	–	–	–	–	1	<1
H	HA	1	<1	–	–	–	–	1	<1
	HB	4	<1	–	–	2	<1	6	<1
Q	Qs	922	39	67	13	274	59	1263	38
	Q	90	4	1	<1	9	2	100	3
	QA	199	8	20	4	163	35	382	11
	QB	56	2	4	1	30	7	90	3
	QC	425	18	31	6	59	13	515	15
	QD	136	6	9	2	12	3	157	5
	QE	1	<1	1	<1	–	–	2	<1
	QH	10	<1	–	–	1	<1	11	<1
	QL	4	<1	–	–	–	–	4	<1
	QP	1	<1	1	<1	–	–	2	<1
R	R	6	<1	–	–	–	–	6	<1
T	Ts	1408	60	406	79	179	39	1993	60
	T	22	1	3	1	6	1	31	1
	TA	761	32	105	20	75	16	941	28
	TC	1	<1	–	–	1	<1	2	<1
	TE	–	–	1	<1	–	–	1	<1
	TJ	110	5	75	15	27	6	212	6
	TK	36	2	17	3	4	1	57	2
	TL	304	13	194	38	52	11	550	17
	TN	42	2	6	1	10	2	58	2
	TP	63	3	4	1	3	1	70	2
	TS	69	3	1	<1	1	<1	71	2
U	U	–	–	–	–	1	<1	1	<1
	UG	2	<1	1	<1	–	–	3	<1
V	VK	1	<1	–	–	–	–	1	<1
None		4	<1	39	8	5	1	48	1
Total		2351	100	514	100	461	100	3326	100

DISCUSSION

FORMAT DISPERSION

This study supports the findings of earlier engineering citation analyses by confirming the importance of journal literature to engineering researchers; however, citation patterns differed somewhat from patterns observed in earlier aerospace engineering citation analyses (Conkling et al., 2010; Eckel, 2009; Fransen, 2012; Kayongo & Helm, 2012; Kriz, 1978, 1984; Sridhar, 1985; Williams & Fletcher, 2006). Previous studies provide evidence that some of these differences are attributable to different user groups, where thesis and dissertation authors cited journal articles at a lower rate and monographs at a higher rate than did faculty. One explanation may be that students need more foundational background material and may not be ready to assimilate the expert research findings reported in articles. Comparing formats reported in this study to previous studies of aerospace engineering, the percentage of journal articles cited are higher and monographs lower (see Table 1). Conferences were the second most frequently cited format type in this study, but were cited less frequently than many previous aerospace engineering citation studies. Reports and government documents were not expected to be cited as much as journals, monographs or conferences, but it was somewhat unexpected to see these formats cited so infrequently within a discipline such as aerospace engineering.

As indicated in the Results section, title dispersion was found to be greater for journals cited than the 80/20 rule would predict. Despite the lack of previous citation analyses calculating journal title dispersion based on the 80/20 rule, some generalized comparisons can be made. The TAMU Aerospace Engineering faculty relied on a higher number of journals (i.e., greater title dispersion) for the majority of their citations than did science researchers reported by Nisonger (2008) in his review of citation analyses. However, the present study confirms the findings of Sridhar (1985) who reported that 11% of the journals cited by his "space technologists" accounted for 59.96% of citations. The present analysis found that 11.7% of the journals cited by TAMU Aerospace Engineering Faculty account for 59% of citations.

Conference proceedings and monographs were cited much less frequently and so discussion of title dispersion is less meaningful; however it is worth noting that the 12 most cited conference proceedings account for 50.2% of the 514 conference paper citations. The most cited monograph [Schaub and Junkins (2003) *Analytical Mechanics of Space Systems*], which was cited 11 times, accounts for 2.4% of the 461 monograph citations. Slightly less than half of the monograph citations were cited only once. For many monographs not owned or accessible online, TAMU Libraries own a newer and/or older edition. Perhaps faculty cite foundational background information from monographs in their personal collections.

SUBJECT DISPERSION

The results of this study support the findings of Williams and Fletcher (2006), but contrast the findings of Fransen (2012). TAMU's Aerospace Engineering faculty and Williams and Fletcher's (2006) thesis authors cited more journals classed in technology (Ts) followed by science (Qs), while Fransen's (2012) thesis and dissertation authors cited more journals classed in sciences followed by technology.

A more detailed analysis at the LC subclasses level in this study revealed additional patterns and differences by format not documented in previous studies. More specifically, aerospace engineering faculty utilized materials from different disciplines and that discipline usage varied by format (Table 6). With respect to journals, material science is one of the major research areas within TAMU University's Department of Aerospace Engineering and may explain the reliance on the journals in the TAs. Nevertheless, it was surprising to see so few TL journals cited among aerospace engineering researchers. The usage of conferences was as expected in terms of LC subclasses in that TLs were the most frequently cited, followed by TJs and then TAs. Cited monographs included QAs and QCs among the top LC subclasses. As indicated in the Results section, theses monographs were primarily general works, treatises, and textbooks. Additional research would be needed to confirm, but these mathematics and physics texts are most likely cited for foundational material (e.g., formulas and scientific laws).

AGE DISPERSION

As indicated in the Literature Review, the age of materials in previous engineering citation analyses are reported in a variety of ways making comparisons difficult. The average age for the journal articles, conference papers, and monographs were 12.5, 8.8, and 20.6 years, respectively. However, age ranges and rather high standard deviations associated with the average ages indicate considerable scatter. Like Eckel (2009) and Fransen (2012), monographs had the largest average age, followed by journal articles and then conference papers. While there are differences, these average ages are similar to those reported by Eckel (2009) and Fransen (2012). TAMU Aerospace Engineering faculty did cite older material. All three major formats included citations to publications that were over 100 years old, which is older than the 66 years that Williams and Fletcher (2006) reported for aerospace engineering theses. However, the oldest publication reported in the present study was similar to the 148 years found by Conkling et al. (2010).

IMPLICATIONS AND CONCLUSION

Unlike previous citation analyses of aerospace engineering, the present study focused on faculty publications and included a subject analysis of the most cited formats. These results have implications for collection management that will inform approval plans, selection/deselection, storage, and purchase of online journal backfiles. Comparing these findings to previous studies suggests the need to assess collections for individual user groups in order to develop balanced collections that will meet the curricular and research needs along the novice–expert continuum.

Journals were the most cited format, but their large title dispersion observed in this study, coupled with the breadth of science and engineering subjects represented in the three major formats, emphasize the interdisciplinary nature of aerospace engineering and its foundation in science and mathematics. The subject areas most heavily cited by TAMU Aerospace Engineering faculty (materials, mechanics, control, and mathematics) are scattered throughout the LC classification scheme, thus requiring the aerospace engineering librarian to consider subject areas beyond aerospace engineering. Citation analyses within and across engineering, science, and mathematics should be used to compile lists of important journals and society conferences. Collection development policy statements and approval plan profiles must be routinely reviewed and updated as programs, curricula, and research trends evolve.

TAMU Aerospace Engineering faculty cited older monographs, many of which were in mathematics and science, even when newer editions were available. The reliance on older monographs observed in this study influences deselection and storage decisions, as well as acquisition of "classic" texts as e-books when available.

This study underscores the necessity of cooperation and collaboration among subject selectors, as well as the need for collection development policies that reflect the realities of the literature actually used rather than assuming department needs will align neatly into a narrowly defined LC classification.

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