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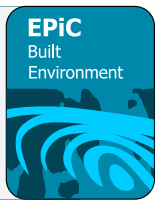

Academic Collaboration in Journal Publications: Pilot Findings from a Sustainability Perspective

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Abstract

Recent improvements in the AEC industry, such as Building Information Modeling (BIM) and lean construction and sustainability, require that the design and construction process be approached from a holistic and collaborative manner. From an academic perspective, collaboration also is an important teaching and research component that allows for a well-rounded understanding of the AEC industry. However, very little research has been performed on collaboration in the AEC disciplines, specifically interdisciplinary collaboration. As a starting point, this paper focuses on academic collaboration in journal publications related to sustainability and building performance. The authors provide bibliometric and thematic analyses of three 2018 research publications related to building performance and written by faculty affiliated with construction departments. The main goal of the paper is to provide preliminary findings about which AEC disciplines were included and which themes were prevalent in collaborative publications. Preliminary findings indicated themes related to performance analysis of buildings and / or building components; indoor environmental quality; decision-making and evaluation methods; and life cycle assessment. Results can be used to identify potential areas that are conducive to collaborative work between construction and other AEC disciplines in order to stimulate more interdisciplinary collaboration within AEC research.

1 Introduction

The architecture, engineering and construction (AEC) industry is a fragmented industry. This fragmentation often hinders integration and collaboration among its various stakeholders, which negatively affects productivity. In order to improve performance and reduce adversarial relationships, the AEC industry is gradually moving toward more collaborative work (Forgues & Koskela, 2009). As a result of this trend, AEC companies are making changes to their professional environments and

processes to increase internal (employees) and external (partners / stakeholders) collaboration (Forgues & Koskela, 2009). This move is critical for the AEC industry to be able to improve its performance. Key concepts and processes that have been used to encourage collaboration are building information modeling (BIM) and lean construction and sustainability, which can be paramount in this process (Becerik-Gerber, Gerber, & Ku, 2011).

BIM is an approach to the whole building design and construction process that involves an information management process that can be used throughout the life cycle of the building to facilitate the collaboration of several industry stakeholders (Sacks et al., 2018). In addition, lean practices can significantly increase design and construction collaboration by (1) connecting the stakeholders and improving the relationships among them; (2) enhancing the flow of information, for example, through BIM; (3) implementing a collaborative pull planning; and (4) implementing weekly work plans during the design and construction phases with the participation of relevant team members to enhance design and construction integration (Koskela, Ballard, Howell, & Tommelein, 2002; Sacks, Radosavljevic, & Barak, 2010). The goal of lean construction is to "design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value" (Koskela et al., 2002, p. 211).

It is interesting to notice that, under the lens of environmental sustainability, waste means pollution. In fact, sustainability and lean construction share many concepts, mainly because both focus on eliminating various forms of waste and increasing the efficiency of processes and products as a way to reduce resource consumption. This goal for buildings to become more efficient and reduce resource consumption is moving the AEC industry toward more sustainable practices (Dodge Data Analytics, 2018; Keeler, Clevenger, & Atadero, 2013).

It is important to emphasize that although BIM, lean construction, and sustainable building provide a holistic and transparent approach to design and construction, they require effective collaboration between team members to be fully beneficial to a project. While industry has increasingly focused on collaboration, academia has been slower to pay attention to it. From an undergraduate teaching perspective, previous research exists and has indicated that few construction programs facilitate construction students taking classes in other AEC disciplines (de Cresce El Debs, Shaurette, & Wilder, 2017; Kovacic, Filzmoser, & Denk, 2014).

Additionally, from a research perspective, there is a lack of studies looking at how much academic collaboration exists today among construction faculty and other AEC-related disciplines. This is especially important since collaboration between AEC disciplines is essential for the processes that require a holistic approach to building and design. A study by Monson, Dossick and Neff (2015) is one of the few to have explored collaboration in AEC research. These researchers have taken a thematic perspective by studying papers that include topics relevant to more than one AEC discipline, though they have not explored author affiliations. They have identified eight core themes for AEC collaboration – social foundations, communication practices, organizational studies and management, technology, knowledge and learning, leadership and power, identity, and integration measures – by searching papers using pre-determined key words in eight journals (Monson et al., 2015). Most of the publications that Monson et al. (2015) identify relate to the management aspect of construction, some of which can be related to lean construction approach (for example, evaluating an integrated project delivery project). By contrast, the papers selected for the technology core mostly relate to BIM usage. Only one paper relates to sustainability and was included in the "integration measures" core (Monson et al., 2015).

Bibliometric analyses are useful to measure collaboration in research and have been performed in other disciplines, specifically measuring quantitative aspects of scholarly publications (Hood & Wilson, 2001). Melin and Persson (1996) have described the application of this type of research and noted that writing joint papers is only one form of academic collaboration. Other research collaborations may yield other types of products, such as patents, and some co-authored papers may not represent true collaborative research (Melin & Persson 1996). Despite that, bibliometric studies are widely used as a way to measure collaboration, though previous research suggests that findings from those studies should

be coupled with additional data for a more complete analysis of collaborative efforts (Ponomariov and Boardman, 2016).

Thus, the purpose of this study is to explore how much collaboration has taken place in AEC published research, focusing specifically on the collaboration between construction and other AEC faculty researchers occurring in journal publications. The present paper provides initial findings that can and should be built on at a later phase to reveal a more complete review of research collaboration. The authors will use a sustainable construction perspective and focus on building performance. A secondary goal is to evaluate the methods used in the present pilot study, which could be replicated for an expanded scope of the analysis of collaboration on key AEC concepts and processes. To achieve this goal, the authors address the following research question: Which topics in academic journals have most often been authored as collaborative endeavors between faculty of construction and other AEC related departments? We also pose the following sub-question: How is collaboration structured? This includes verifying whether authors come from the same or different institutions and determining whether the work comes from a department that already includes construction and an additional AEC discipline.

The results of this study will (1) reveal which topics are of interest both to construction and other AEC faculty as a way to engage and stimulate more interdisciplinary research in the current scenario, and (2) describe the challenges of this type of research within AEC. This type of research is especially interesting in relation to the three aforementioned key concepts and processes that span the boundaries of a given AEC discipline. In this study, we define interdisciplinary research as combining and integrating the methods and insights offered by various disciplines; i.e. it crosses and mixes traditional boundaries between disciplines (Lawrence, 2010). In addition, the authors provide a list of recommendations related to the present method to guide others in pursuing this type of research within AEC.

2 Methodology

This study uses systematic literature review and bibliometric analysis to identify and assess current literature involving academic collaboration between construction faculty and other AEC-related disciplines. Considering the envisioned purposes and the exploratory character of this study, the researchers selected journals based on the following criteria: (a) subject areas related to environmental sustainability and focused on construction and building energy; (b) classified as Q1, or the best quartile for the selected area according to Scimago Journal & Country Rank (SJR) consisting of the subject area 'Engineering' and subject category 'Building and Construction'; and (c) published in 2018.

Only one year was evaluated because of the exploratory nature of the present study. Environmental sustainability was chosen as a focus because it is one of the four topics previously identified in the introduction section as topics requiring an interdisciplinary approach. The search resulted in three main journals as sources of data to be assessed: Building and Environment (SJR 1.879); Energy and Buildings (SJR 1.934); and Journal of Building Performance Simulation ((SJR 1.186). Applied Energy and Energy journals were not included because their emphasis on energy led to a more mechanical engineering focus.

Following Melin and Persson's (1996) recommendations, we have defined the aggregation level to be departmental affiliation. This choice was made because it allowed the authors to code each department as the AEC discipline to which it was most closely related. A limitation of this analysis is that certain authors potentially could be included in departments other than their original AEC fields, for example, an academic trained in architecture who is currently affiliated with a construction department. This approach also poses challenges because some departments that are related to AEC might encompass more than one discipline, such as an 'Institute of Construction and Architecture,' and some departments that are related to AEC might have names that are not directly related to architecture,

engineering, or construction, such as a department of Built Environment (challenge #1). In the case of the 'Institute of Construction and Architecture,' the code reflected its interdisciplinary nature by assigning it to both the construction (C) and architecture (A) disciplines. For a department named 'Built Environment,' a specific code is used (B, for built environment). In both cases, departments with multiple affiliations and departments of 'built environment' warrant further investigation to evaluate whether the work is actually of interest to multiple AEC faculty.

After affiliation was coded, we assessed the authors' affiliations with each article to identify those involving academic collaboration between construction faculty and other AEC-related disciplines. Then, an investigation was performed to identify (1) the interdisciplinary collaboration types (which disciplines and whether collaboration was performed within the same institution or not); and (2) the researched topics within the articles involving interdisciplinary collaboration. Journal articles authored by faculty from departments that serviced more than one AEC discipline were excluded from the thematic analysis because these require further exploration. Topics were developed by the researchers based on title, abstract, and keyword information. The impact of papers per topic of collaboration also was assessed by counting the citations papers obtained by December 2019. The authors provide aggregated descriptive statistics for paper citations under each theme and describe the three most cited papers. A visual summary of the methodology is provided in Figure 1.

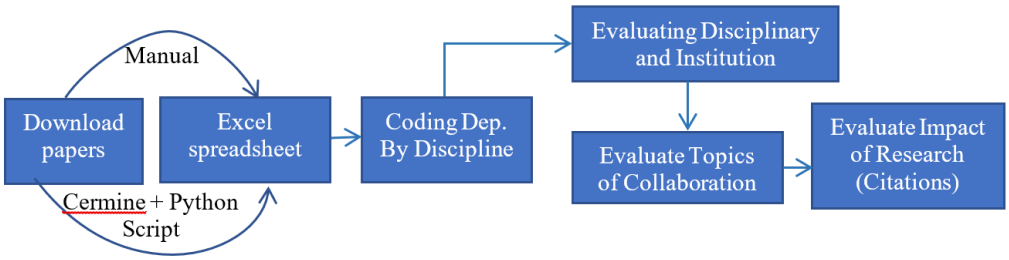

Figure 1: Conceptual Framework

The researchers collected all the articles published and assigned to volumes in the three selected journals; the total number of articles was 1455. Papers were downloaded and, initially, data was entered manually into an excel spreadsheet. However, since the number of published papers in 2018 for two of the three selected journals (Energy and Buildings = 828, Building and Environment = 584) was substantial, two additional challenges emerged: daily limits for download of journal articles (challenge #2) and the need for an automated process for populating the spreadsheet (challenge #3). Daily download limits slowed the research process, but dealing with a large data set became the main issue to be solved. To mitigate that issue, the authors used Cermine (Tkaczyk et. al, 2015), an open source application designed to extract affiliation information from scientific papers and change pdf files to the '.xml' file format. After that, a Python script was developed by the researchers to extract the information from the '.xml' file and convert it to a spreadsheet format (.csv) for coding.

3 Preliminary Results

The distribution of relevant papers varied greatly by journal. While the Journal of Building Performance Simulation yielded no relevant results, Building and Environment had 21 and Energy and Buildings had 49 articles authored by construction affiliated faculty. Comparing these results to the

total number of papers published that year revealed that contributions from construction related disciplines amounted to close to 4.8% of the total number of published papers (Table 1).

Journal	# of relevant papers (total papers)	% of relevant papers to total of published papers
Journal of Building Performance Simulation	0 (43)	0%
Building and Environment	21 (584)	3.6%
Energy and Buildings	49 (828)	5.9%
Total	70 (1455)	4.8%

Table 1: Relevant papers (papers authored by faculty from construction related department) – 2018

In terms of the type of collaboration, it is interesting to note that this percentage varied between Energy and Buildings and Buildings and Environment. Even so, collaborative research – here defined as research including more than just faculty from a construction related department – turned out to be more frequent than non-collaborative research, which is promising. The main type of collaboration in both journals was between construction and other AEC disciplines (n=45), and the number of papers authored only by faculty affiliated with construction departments was seven for Energy and Buildings and three for Building and Environment. Ten papers were authored by faculty of single departments that service multiple AEC areas. Other AEC areas include departments of engineering, built environment department, building sciences, sustainable building, environmental science, and real estate development. The Journal of Building Performance was excluded because it had no papers in 2018 that were authored by faculty of construction related departments. Table 2 summarizes the findings for the Buildings and Environment and Energy and Buildings journals.

Type of Collaboration	# of Articles		Same University		Between Universities	
Journal[a]	E	B	E	B	E	B
Construction and other AEC discipline(s) Simulation	30	15	2	2	28	13
Construction (without collaboration outside construction discipline)	7	3	5	2	2	1
Work produced exclusive by collaborative departments[b]	7	3	7	3	-	-
Total	44	21	18	7	31	14

Table 2: Collaboration between construction and other AEC disciplines (2018)

[a] Collaboration between construction and other AEC disciplines (2018)

[b] These works are authored by faculty of single departments that service more than one AEC discipline. In one case it includes a collaborative department and a NU institution.

The authors also have identified 5 publications resulting from collaborations between faculty of construction related departments and non-academic institutions (NU) that do not include other AEC disciplines. This collaboration was not further analyzed in this paper because it did not involve collaborations between academic departments. NU institutions include non-governmental organizations and institutions not affiliated with any university or industry.

In relation to university affiliation, collaboration in papers authored only by faculty affiliated with construction related departments occurred mainly within the same university, while collaboration

between construction and other AEC disciplines is more common between universities rather than within the same university.

3.1 Main topics for collaborative research

The authors then analyzed the resulting papers that were authored by more than one department (n=45) to group them into themes. Papers could have only one main theme. Four main themes were defined based on the relevant papers: (a) performance analysis of buildings and / or building components (n=18); (b) indoor environmental quality (n=14); (c) decision-making and evaluation methods (n=8); and (d) life cycle assessment (n=5). The most frequent theme, found in about a third of the publications, was performance analysis. Papers related to this topic were much more prevalent in Energy and Buildings than in Building and Environment.

Main Topic	Energy and Buildings	Building and Environment	Total
Performance analysis (building and / or components)	15	3	18
Indoor environmental quality	6	8	14
Decision-making and evaluation methods	5	3	8
Life cycle assessment	4	1	5
Total	30	15	42

Table 3: Main topics of interdisciplinary AEC collaborations

Now the authors present a brief discussion of each of the main themes identified in Table 3. These themes appeared in research that included collaboration between construction and other AEC disciplines.

- *Performance analysis (building and / or building components)* (n=18) – This theme is addressed by almost half of the analyzed papers. Within this category, papers dealt with thermal or hygrothermal performance of buildings or building elements (n=9), energy consumption at the urban scale (n=1), energy consumption in buildings (n=3), building performance for sustainable certifications (n=2), commissioning (n=1), and building envelopes (n=2). Most of the work is related to thermal performance, such as the work by Sanchez-Resendiz et al. (2018) and Ji et al. (2018), but some of the work on thermal and hygrothermal performance also has implications for energy consumption (such as Wang et al., 2018). Publications under this topic average 10 citations (with a minimum of 2, a maximum of 30, and a median of 7 citations per paper).
- *Indoor environmental quality (IEQ)* (n=14) – This theme encompasses topics such as the effects of IEQ on occupants' behavior and comfort and the effects of occupants' behavior on IEQ (n=11), as well as interactions among occupants with specific building elements, such as windows (n=2) and computational fluid dynamics (n=1). Research targeting the impact of thermal comfort seems to be prevalent, such as in the work by by Fang et al. (2018a) and Fang et al. (2018b). It is interesting to note that one of the papers in this group proposes a modeling technique to predict user behavior for operation of windows and lights (Naspi et al., 2018), which relates secondarily to decision-making and evaluation methods. Publications on this topic also average 10 citations (with a minimum of 3, a maximum of 18, and a median of 10 citations per paper).
- *Decision-making and evaluation methods* (n=8) – The main focus of this theme is a study of modeling and prediction techniques. This thread includes papers related to the modeling of

energy use (n=4), the challenges of risk management in building renovations (n=1), design decision making (n=2), and sustainable rating systems (n=1). Some papers, such as Tagliabue et. al (2018) on energy consumption in renovation and Invidiata et al. (2018) on design decisions and energy consumption discuss more than one theme but were associated with the one considered most relevant. Publications under this topic have slightly higher impact than the previous two topics, with an average 14 citations per paper (a minimum of 2, a maximum of 41, and a median of 11.5 citations per paper).

- *Life cycle assessment (LCA)* (n=5) – In this theme, LCAs were made in three instances to evaluate gas emissions (greenhouse gases or CO2) (n=3). A fourth paper evaluated life cycles of prefabricated elements (n=1) (Zhu et. al, 2018), and a fifth considered the analysis for long term costs of a specific element (n=1). All but one of the papers in this category were published under Energy and Buildings. With an average of 12 citations per paper (a minimum of 1, a maximum of 20, and a median citation number of 15 per paper), publications under this topic have an impact similar to that of the first two topics presented.

As seen in thematic analysis, the number of citations per journal article varies significantly. A different impact may emerge as years go by, given that the present analysis takes into consideration articles published in the 2018 issues of the two journals. Three works are most frequently cited among all four topics: a study by Fan, Xiao, Li and Wang (2018) on the use of big data for energy efficiency (under the 'decision-making and evaluation methods topic') with 41 citations; the work of Ding, Fan, Tam, Bian, Li, Illankoon and Moon (2018) on the implementation of an evaluation system for green buildings (topic 'Performance analysis') with 30 citations; and a study by Zou, Xu, Sanjayan and Wang (2018) on a 10 year review of building energy performance research (topic 'Performance analysis'), with 21 citations. Interestingly, an individual from the Construction Management and Real Estate department of Shenzhen University is one of the authors in two of these papers, and the Department of Civil and Construction Engineering from Swinburne University of Technology has authors in two of the three papers. All authors from the three most cited papers were from universities in China, Honk Kong or Australia.

4 Conclusions and Recommendations

The AEC industry is moving toward more collaborative approaches in an effort to improve efficiency. In academia, research collaboration across AEC disciplines exists, but little research has provided insight into this collaboration. Our research provides results from a small-scale pilot study to start this discussion and to provide a list of common topics that were found to engage faculty of construction and other AEC related disciplines. Three journals focused on building performance were analyzed for the year of 2018 publications, though only two had papers authored by faculty affiliated with construction related departments. Collaborative research among faculty of different AEC departments was found to be more frequent than non-collaborative research, which is encouraging given that processes like lean construction and sustainability require a collaborative approach. Papers involving construction and an additional AEC department were further analyzed for themes. The main themes identified for collaborative AEC research were: performance analysis of buildings and / or building components; indoor environmental quality; decision-making and evaluation methods; and life cycle assessment. About a third of the papers and two of the most cited analyzed papers were related to performance analysis, which suggests that this topic is conducive to improving collaboration for construction and other AEC disciplines.

The findings are limited to a one-year review of collaborative research in journals that focus on building performance, which can be related to sustainable construction. Data analysis of multiple years

may or may not reflect the same findings. The authors were limited to the analysis of departmental affiliation as provided in the papers, and only analyzed title, keyword, and abstract for the thematic analysis. As suggested by previous research (Melin & Perssons, 1996), scientometric analysis should be used in conjunction with other measures of collaboration to gain a better picture of academic collaboration. Despite these limitations, the present research successfully combines bibliometric analysis with thematic analysis to evaluate themes that potentially can be explored collaboratively by multiple AEC disciplines in academic research.

The present research also faced certain challenges that need to be taken into consideration by researchers who might perform similar types of research. Three main challenges were identified: (1) correctly identifying affiliations when the names of some AEC related disciplines vary greatly and departments such as "built environment" are difficult to classify); (2) since the amount of published research has recently increased, large amounts of data had to be downloaded, triggering daily download limits by publishers; and (3) the need to establish more automated methods of data extractions and analysis due to the existence of large datasets.

Future research may pursue a number of inquiries: expanding the amount of years analyzed to provide a historical analysis of collaboration; expanding the scope of journals to include journals more focused on construction management; using other qualitative measures of research collaboration in AEC disciplines; and examining the use of automation techniques to help with data mining and analysis of large amounts of data.

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