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Cross-boundary collaboration in waste management research: A network analysis

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ABSTRACT

This paper aims to illustrate the cross-boundary research collaboration (CBRC) landscape of waste management (WM) by various collaboration networks. Through a set of rigorous procedures, a total of 15,396 research papers were extracted from eight subject-related journals published between 1981 and 2016. The authors utilized *CiteSpace*, a Java programme that helps visualize and dissect patterns in scientific literature, to evaluate the content through individual, institutional, national, and disciplinary perspectives. The evaluations of three former perspectives revealed a steady rise in CBRC within WM over the last thirty-five years, although the overall intensities proved fairly low. Inter-individual collaboration groups were limited to their respective regions and only loosely connected, but as more and more academic institutions and universities engaged in WM research, the number and quality of the collaborations increased. Developed countries, chiefly in North America and Western Europe, comprised the bulk of the WM research, whilst the mounting contributions from developing countries, China in particular, forecasts greater diversity in the future. The analysis also suggested that the intensity of the interdisciplinary collaboration network declined slightly, however, the intensity proved low to begin with. Previous WM research focused more on "hard" technologies than "soft" measures. Future endeavors to encourage CBRC in WM should promote more innovative research to tackle waste challenges globally in a sustainable way.

1. Introduction

Managing waste is a major global sustainability challenge that demands combined efforts from a myriad of public and private stakeholders. Increasingly multifaceted, no single discipline, let alone single researcher, can possess the necessary knowledge to maximize waste management (WM) efficiency. Given the drift towards internationalization and globalization of knowledge creation, a growing number of scholars and research institutions seek to conduct their frontier research outside their immediate surroundings. By sharing workloads, specific expertise and skills, equipment or resources (Altbach and Knight, 2007), research collaboration helps resolve personal research limitations. Research collaboration is defined as researchers working together to produce new scientific knowledge, insights, methodologies, solutions and/or inventions (Katz and Martin, 1997). Research collaboration can operate in a decentralized manner, supported by user-friendly and expedient online platforms, ranging from email exchange to online manuscript submission systems, e.g., ScholarOne® or EditorialManager®. Cross-boundary research collaboration (CBRC) can provide a platform for researchers to communicate research strategies and innovations across the traditional institution, nation, and discipline boundaries. To incorporate the multidisciplinary and multinational nature of WM, research policymakers seem to encourage multi-institutional collaborations in order to develop complex, intellectually diverse projects (Carley, 2006), e.g., the *European Waste Management Cluster* and the *Urban Strategies for Waste Management in Tourist Cities*. Smaller scale, but arguably more active CBRCs materialize more organically, forming through online communication and idea sharing. This is not to say that such CBRCs lack big scale funding as many receive backing from major international bodies like EU agencies, which characteristically insist on cross-boundary collaborations.

Previous studies have tended to understand CBRC by investigating the connections and structures of social networks formed in knowledge innovation (Tortoriello and Krackhardt, 2010) and information sharing (Pardo et al., 2010). Network structure, in a broad sense, concerns the pattern of relationships generated by direct and indirect connections between actors (Hoang and Antoncic, 2003). In CBRC, one of the most significant networks is a co-authorship network. The "explicit product" of a scientific collaboration between two or more authors (Newman, 2004), co-authorship represent a kind of tangible proof that

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Table 1
Top eight journals most relevant to WM and their corresponding quantity of papers.

Journal Title	Year of First Volume	2016 Impact Factor	Quantity of Papers Collected	h-index	Average Citations per Item	Sum of Times Cited	Without Self Citations
Journal Of Environmental Management	1973	4.01	910	54	17.31	15,748	15,392
Resources, Conservation And Recycling	1988	3.313	1200	67	21.59	25,910	23,974
Journal Of Cleaner Production	1993	5.715	1364	58	15.8	21,549	19,475
Waste Management & Research	1983	1.803	1537	49	10.85	16,680	15,110
Environmental Science &Technology	1967	6.198	1839	127	44.77	82,327	80,355
Journal Of Hazardous Materials	1976	6.065	2555	111	32.74	83,651	81,096
Water Science & Technology	1970	1.197	2918	72	14.1	41,152	39,720
Waste Management	1983	4.03	3073	83	21.2	65,140	58,201

Data source: "Year of First Volume" and "2016 Impact Factor" are collected from the official website of the journals; "h-index", "Average Citations per Item", "Sum of Times Cited" and "Without Self Citations" were collected from Web of Science when searching for the papers about WM on Nov, 13 2017, this data is based on the searched papers.

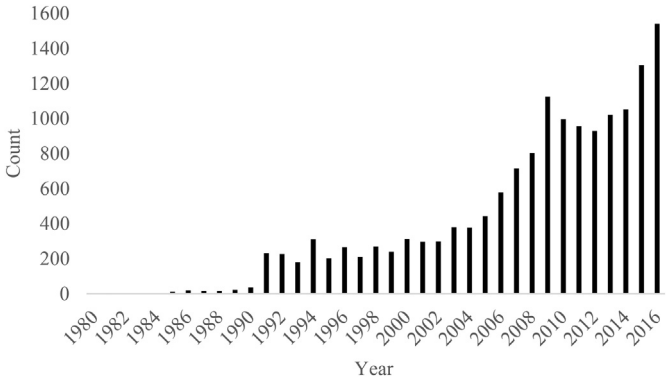

Fig. 1. The number of papers published from 1981 to 2016.

collaboration has occurred. Whenever a scholar publishes a co-authored article, he or she has created an individual co-authorship network (Li et al., 2013). In the meantime, with their institutional, national and disciplinary information, inter-institutional, inter-national and inter-disciplinary networks have also been created. Modeling CBRC networks provides valuable insight into the patterns of collaborations among individuals, institutions, nations, and disciplines, the emergence and the propagation of thoughts in academic society (Cross et al., 2002). WM research, where different expertise is required, saw intensive CBRC. However, a definitive analysis of CBRC networks in WM domain has long been overdue. This article seeks to shed light on the cross-boundary collaborative relationships in WM research on four cross-boundary perspectives using a network analysis. It does so by investigating 15,396 relevant research papers extracted from eight highly relevant journals published over the past thirty-five years. This paper is organized as follows, section 2 reviews the prevailing literature of WM research, CBRC in other relevant areas, and analytical tools; section 3 presents the research methods of data collection and analysis; section 4 reports the detailed analysis and results from the four cross-boundary perspectives, namely, individuals, institutions, nations, and disciplines, together with longitudinal analyses of these four aspects respectively; the last two sections discuss in depth the problems and solutions facing global and interdisciplinary collaborations in the WM field and conclude the paper.

2. Literature review

2.1. Why WM demands joint efforts

WM includes all the activities and actions required to manage waste from inception to final disposal (Division, 1997), such as waste collection, transport, treatment by thermal or biological processes, disposal, monitoring, and regulation to name a few. WM exemplifies a global sustainability dilemma that calls for the efforts of governments, private sectors, research institutions, scientists and the general public (Vithanage et al., 2014). In the age of economic globalization, traditionally local WM activities, e.g., waste collection, can impact another continent's environment. Meanwhile, the economic development in emerging countries has triggered an exponential increase in waste generation. For example, China's municipal solid waste amounted to 148 million tons in 2006, of which 91.4% became landfill, 6.4% incineration, and 2.2% compost (Zhang et al., 2010). Similarly, India suffers from the massive pileup of e-waste stemming from its high speed economic and technological growth (Sinha-Khetriwal et al., 2005), along with that of more typical urban waste. WM concerns escalate as cities and countries develop, but global joint research in parallel with urbanization can enable knowledge sharing, informed response and innovation exchange in order to amend WM performance in developed and less developed countries.

Research is the action of creating and sharing new knowledge to guide practices (Appleton, 1993). Numerous researchers have entered the field of WM, exploring both hard and soft approaches. "Hard" approaches denote scientific and technological means of reducing, reusing, and recycling abandoned resources. For example, researchers have spent countless time and effort exploring the reuse of solid waste in order to replace natural resources, e.g., reusing waste iron as a partial substitute for sand in concrete (Ismail and Al-Hashmi, 2008a), plastic waste as an aggregate replacement to mix concrete (Ismail and Al-Hashmi, 2008b), and converting fly ash into construction materials, fertilizer and other geotechnical applications (Ferreira et al., 2003). They have also endeavored to find treatments to remove pollutants or collect biogas from wastes (Kamala and Rao, 2012). While soft approaches represent economic or managerial measures, for instance estimating overall waste generation (Lu et al., 2017), designing from waste (Osmani et al., 2008), public policies (Goorhuis et al., 2012), economic analysis (Lu et al., 2015), and management strategies (Shen et al., 2004). CBRC plays a crucial role in devising hard and soft approaches, tackling the global issue, and developing opportunities for mutual WM learning and idea sharing (Berkes, 2009). However, how and to what extent the global body of researchers of this field conduct CBRC is still under-researched.

Research collaboration can take various forms. Examples range from online sharing of data and sources, correspondence by mail, presentations at workshops and conferences, visits to foreign laboratories, to the exchange of papers. The most obvious and easily measured form of collaboration is the writing and publication of research findings (Laudel, 2002). One can study the collaboration of an academic publication from different aspects to understand the CBRC patterns between individual researchers, institutions, nations, and disciplines. Such activities automatically generate networks comprised of nodes,