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Insights from hashtag #supplychain and Twitter Analytics: Considering Twitter and Twitter data for supply chain practice and research

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ABSTRACT

Recently, businesses and research communities have paid a lot of attention to social media and big data. However, the field of supply chain management (SCM) has been relatively slow in studying social media and big data for research and practice. In these contexts, this research contributes to the SCM community by proposing a novel, analytical framework (Twitter Analytics) for analyzing supply chain tweets, highlighting the current use of Twitter in supply chain contexts, and further developing insights into the potential role of Twitter for supply chain practice and research. The proposed framework combines three methodologies – descriptive analytics (DA), content analytics (CA) integrating text mining and sentiment analysis, and network analytics (NA) relying on network visualization and metrics – for extracting intelligence from 22,399 #supplychain tweets. Some of the findings are: supply chain tweets are used by different groups of supply chain professionals and organizations (e.g., news services, IT companies, logistic providers, manufacturers) for information sharing, hiring professionals, and communicating with stakeholders, among others; diverse topics are being discussed, ranging from logistics and corporate social responsibility, to risk, manufacturing, SCM IT and even human rights; some tweets carry strong sentiments about companies' delivery services, sales performance, and environmental standards, and risk and disruption in supply chains. Based on these findings, this research presents insights into the use and potential role of Twitter for supply chain practices (e.g., professional networking, stakeholder engagement, demand shaping, new product/service development, supply chain risk management) and the implications for research. Finally, the limitations of the current study and suggestions for future research are presented.

1. Introduction

Recently, businesses and research communities have paid a lot of attention to social media (Aral et al., 2013; Harris, 2014; Kalampokis et al., 2013). Businesses are primarily interested in the role and use of social media for marketing purposes, including brand management and product and service promotion. Research communities, made up of members from diverse academic fields, have been investigating the potential use of data (also referred to as "big data"), created and stored through social media technologies or platforms, to develop new insights in different areas, including stock price predictions, prevention of epidemics, early event monitoring, election predictions, crisis management and humanitarian relief, brand management, public relations, information diffusion, and public opinions (Arias et al., 2014; Hughes and Palen, 2009; Inauen and Schoeneborn, 2014; Williams et al., 2013). Industry communities (e.g., companies, professionals, associations) have explored many potential uses of social media as a medium for marketing, customer engagement, recruitment, sales forecasting, and educating.

The field of supply chain management (SCM) has been relatively slow in identifying the potential role and use of social media for research and practice. While there are a growing number of studies and reports on the use of data and analytical capabilities for SCM (Chae and Olson, 2013; Hazen et al., 2014; Trkman et al., 2010), the focus has generally remained on traditional data sources (e.g., enterprise resource planning) and analytical techniques (e.g., optimization algorithms), and their use for and impact on supply chain planning and execution. Nevertheless, a small number of seminal articles on the use and potential role of social media in the supply chain have been published in the academic literature and industry press (Casemore, 2012; O'Leary, 2011). Also, there are recent calls for the utilization of big data in the SCM field (e.g., Huang et al., 2014; Smart et al., 2014; Waller and Fawcett, 2013). Big data created in manufacturing alone is close to 2 exabytes (2×1000^6) in 2010, which is more than in any other sectors (McKinsey&Company, 2011). While there are many sources (e.g., sensors, transaction logs) for big data, there is an explosive growth of Web 2.0 applications (e.g., Twitter,

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0925-5273/

Facebook, blogs) in recent years, and, thus, social media largely contributes to the emergence of these big data.

A recent survey of industry leaders and companies (Cecere, 2012) reports that one in three companies is evaluating a big data initiative for SCM. The companies in the survey express confidence in their ability to manage traditionally structured and transactional data, including product traceability data, geo-location and mapping data, and supply chain visibility. However, the survey notes that the companies are least capable of using social media data for supply chain intelligence. Another industry survey (Natoli, 2013) shares a similar story: while logistics providers, manufacturers, and retailers are leveraging traditional supply chain data (e.g., POS), only one percent of those surveyed reported any use of social media data for supply chain planning. An industry expert echoes these situations, "We know social media will transform supply chain processes, but we just don't know how exactly and where to start and why." (Mann, 2014).

In these contexts, we pay attention to one particular social media platform, Twitter. We chose Twitter because, among different social media technologies, Twitter has become the fastest growing social platform, ahead of Facebook and Google+ (Bennett, 2013). Currently, over 270 active Twitter users generate 500 million tweets per day.[1] Customers follow products, services and brands, and discuss them in Twitter (Webster, 2010). Another important reason is that, unlike Facebook data, Twitter data could be considered "open". Thus, research and business communities can access Twitter data using Twitter Application Programming Interface (API) (Twitter, 2013), which has offered them opportunities to access the data in an unprecedented scale and size, and to analyze such data for challenging problems in diverse domains.

The objective of this paper is to improve our understanding of Twitter, in particular (and social media in general), in supply chain contexts. More specifically, the paper proposes a novel, analytical framework (Twitter Analytics) for analyzing supply chain tweets, highlighting the current use of Twitter in supply chain contexts, and further developing insights into the potential role of Twitter for supply chain practice and research. As noted above, there are few research articles and published industry cases on the topic of social media and supply chain. While it is imperative to understand social media and social media data in supply chain contexts, as echoed by industry surveys and academics (e.g., Cecere, 2012; Mann, 2014; Smart et al., 2014), it is clear that there is a lack of understanding of this important topic. To our knowledge, a practical methodology or framework for analyzing social media data, related to supply chain practice (and research), is not readily available. Thus, this research is expected to make important contributions to the SCM community.

Twitter Analytics (TA) combines three types of analytics (or research techniques) – descriptive analytics (DA), content analytics (CA), and network analytics (NA) – each of which focuses on different dimensions in the analysis of Twitter data. This framework is applied to 22,399 tweets and metadata, which were collected using hashtag #supplychain, the most prevalent supply chain-related Twitter hashtag. The result is a large amount of intelligence regarding supply chain professionals and organizations and their Twitter use. The findings are discussed in an organized format around four general questions:

(1) What are the characteristics of supply chain tweets? Are there any patterns of communication and information diffusion?
(2) What supply chain topics or contents are shared in Twitter? Are there any prevalent topics or contents?
(3) What are the characteristics of those Twitter users who are discussing supply chain-related topics?
(4) What are the sentiments of supply chain tweets? What types of supply chain tweets tend to contain sentiment?

These findings help us acquire greater insights into the use and potential role of Twitter for supply chain practices (e.g., stakeholder engagement, hiring supply chain professionals, new product/service development, supply chain risk management), and to further discuss research implications.

We organized the paper as follows: Section 2 presents a brief review of Twitter and the use of Twitter in other areas; Section 3 proposes a framework of Twitter Analytics (TA), along with some relevant studies; Section 4 applies the TA framework to the analysis of 22,399 supply chain-related tweets and metadata; in Section 5, we present a broad range of intelligence from descriptive, content, and network analytics techniques, and further discuss them in the context of supply chain; in Section 6, based on the intelligence, we develop greater insights into the use and potential role of Twitter for supply chain practice and discuss research implications. The final section presents the limitations of the current study and makes suggestions for future research.

2. Background: Twitter and its impacts

Twitter, along with Facebook and Youtube, represents the rapid growth of Web 2.0, or social media applications, in recent years. Since its inception in 2006, this microblogging application has been the fastest growing social media platform. Over 75% of the Fortune Global 100 own one or more Twitter accounts at the corporate level and for their specific brands (Malhotra et al., 2012). People and organizations form dynamic communities through following and being followed by others, and information is disseminated rapidly, as recently exemplified by the stock market's response to a fake tweet from the account of the Associated Press.

A tweet is a message of up to 140 characters. Three types of tweets are found in Twitter: original tweets, replies, and retweets.[2] Original tweets appear in the sender's profile page and Home timeline. Such an original tweet can be retweeted by other users. Also, Twitter users can join the conversation by @replying to others and by retweeting. These tweets are traceable. Twitter offers API to researchers, practitioners, and organizations that are interested in collecting and analyzing tweets (Twitter, 2013). Search and Streaming APIs allow researchers and businesses to collect Twitter data using different types of queries, including keywords and user profiles. While Facebook makes only the data in group and fan pages (e.g., Global Supply Chain Group in Facebook) open to the public, Twitter data is considered "open data".

In recent years, Twitter data has become one of the most popular information sources for practical applications and academic research. There are numerous examples of practical applications of Twitter data, ranging from stock forecasting (Arias et al., 2014; Feldman, 2013), through real-time event and trend analysis using machine learning algorithms (Dickey, 2014), brand management (Malhotra et al., 2012), to crisis management (Wyatt, 2013). It is expected that there will be a rapid growth of Twitter data use for many other applications, including public safety, market prediction, and humanitarian assistance and relief (Dataminr, 2014).

Also, Twitter has already impacted academic research in many fields, including finance (Bollen et al., 2011), healthcare (Park et al., 2013; Terry, 2009), journalism (Lasorsa et al., 2012), information

[1] https://about.twitter.com/company.

[2] https://support.twitter.com/articles/119138-types-of-tweets-and-where-they-appear.

systems (Aral et al., 2013), politics (Gayo-Avello, 2012), marketing (Jansen and Zhang, 2009), communication (Zappavigna, 2011), and psychology (Dodds et al., 2011). In the SCM area, the study of Twitter (social media and big data in general) is rare. As an exception, O'Leary (2011) suggested the use of Twitter for detecting supply chain events and facilitating frequent communication among supply chain partners. Twitter's consequences are expected to be far-reaching in research and to inspire other academic fields.

3. A framework of extracting intelligence from Twitter data

Collecting Twitter data (tweets and metadata) begins with identifying the topic of interest using a keyword(s) or hashtag(s), and requires the use of APIs (e.g., Streaming). This API method allows acquiring 1% of publicly available Twitter data. Twitter data is also available through data providers (e.g., GNIP, DataSift), also known as Twitter Firehoses, which can deliver 100% of Twitter data based on criteria. This is an ideal, but very costly, option. Other social media platforms also provide their API services. For example, Facebook offers Graph API.

While Twitter (and social media) data collection can rely on standardized API services, the analysis of such collected data becomes challenging because the data are less structured (e.g., texts, informal expressions) and more enriched (e.g., user profiles, follower, hashtags, URL) (Daniel et al., 2010) than traditional data (e.g., sales data) found in corporate databases, and the analytical framework or methodology is not readily available. The use of diverse research methods and metrics is necessary to extract intelligence from the highly enriched and unstructured social media data (Chau and Xu, 2012; Daniel et al., 2010; Fan and Gordon, 2014). With this in mind, the rest of this section focuses on developing an analytical framework encompassing such research methods and metrics for extracting intelligence from Twitter data. It consists of three methodologies from different intellectual backgrounds: descriptive analytics (DA), content analytics (CA), and network analytics (NA) with some relevant metrics[3] (see Fig. 1).

3.1. Descriptive analytics (DA)

Twitter data contain a large amount of information, including tweets and metadata (e.g., user information). DA focuses on descriptive statistics, such as the number of tweets, distribution of different types of tweets, and the number of hashtags. Descriptive statistics are widely used in SCM research and practice. For example, researchers always report descriptive statistics about the survey they conducted. The difference lies in the number of metrics. While a small number of metrics (e.g., sample size, response rate, responder profile) are used for the survey data, the enriched nature of Twitter data enables intelligence extraction, using a large set of metrics regarding tweets, users, hashtags, URLs, etc.

A simple, but broad, view of tweet data is a pre-requisite for detailed analyses. Tweet metrics aim to present a simplistic, but essential, picture of the data, using several metrics (number of tweets, word counts, @user per tweet, number of hashtags, etc.) (Bruns and Stieglitz, 2013). These are the gateway for many other metrics. Second, knowing who tweets, replies, and retweets is important both for practitioners looking for business value from Twitter and researchers studying a phenomenon. The user metrics show most active/visible users, groups of users in terms of their activities, and other useful user-related information (Bruns and Stieglitz, 2013). This user information is closely related to the outcome of centrality (or popularity) analysis from network analytics (NA). Finally, a large portion of tweets contain one or more URLs in their texts. URLs could be news releases, reports, articles, and more. Thus, analyzing URLs can reveal what topical interests and information are considered important among Twitter users.

While only these three types of analyses are introduced, other descriptive analyses and metrics are certainly possible and should be used for different problems. However, the use of too many metrics is likely to cause information overload and confusion, rather than intelligence. When using DA, practitioners and researchers should carefully consider a selective list of analyses and metrics according to the questions they are trying to address. Also, the change of analyses and metrics is expected when DA is used for other social media data (e.g., Facebook).

3.2. Content analytics (CA)

Social media data are primarily texts and thus "unstructured" in nature. Thus, it is necessary to use content analytics (CA), which refers to a broad set of natural language processing (NLP) and text mining methods, for extracting intelligence from Web 2.0 (Chau and Xu, 2012). A tweet's text is informal and composed of a short list of words, hashtags, URLs, and other information. Thus, a careful consideration of text cleaning and processing is a prerequisite for intelligence gathering. Also, tweets (e.g., "#SupplyChain of cheap clothing stained with the blood of #Bangladeshi workers – http://nydn.us/181XT2M – via @nydailynews") contain not just information, but also opinions. Thus, advanced text mining techniques, such as sentiment analysis, are the key for extracting such opinions.

Text mining and machine learning algorithms are important components of CA. Text mining transforms unstructured texts (or documents) into formatted data (or documents), using such techniques as tokenization, n-grams, stemming, and removing stop words (unnecessary words) (c.f., Weiss et al., 2005). Those transformed texts can be used for text summarization, key word analysis, word frequency analysis, and text clustering, using machine learning algorithms, such as clustering and association analysis. While CA is found in supply chain research and practice (Georgi et al., 2010; Seuring and Gold, 2012; Vallet-Bellmunt et al., 2011), the approach has been manual or semi-manual, primarily through human interpretations. CA in TA relies on automatic text processing techniques and algorithms, due to the big data nature of Twitter data.

Word analysis is a starting point in CA. It includes term frequency analysis, document summarization, and clustering. Term frequency (TF) is widely used in information retrieval. TF can be combined with n-gram, which helps to identify key phrases from the documents. Overall, these analyses help identify topics of discussion, which also indicate different usages of Twitter according to supply chain contexts. Those identified topics are useful for document-level analysis, using unsupervised machine learning algorithms (e.g., clustering). Document-level clustering can categorize documents, which helps enable detailed analysis of those documents in terms of their categorization. Second, hashtags are an important component of tweets, as they are equivalent to areas or fields of interest used to categorize academic papers (or researchers) or tags used to categorize blog postings. In the above example of a tweet, #supplychain and #Bangladeshi are hashtags. Hashtag analysis includes frequency analysis and association rule mining. Frequency analysis shows the popularity of hashtags. Association rule mining discovers relationships between hashtags. These relationships explain how different areas of business practice (logistics, corporate social responsibility, risk management, etc.) are intersecting in Twitter.

[3] The list of those metrics in Fig. 1 is not exhaustive. It includes only some of the potential metrics.

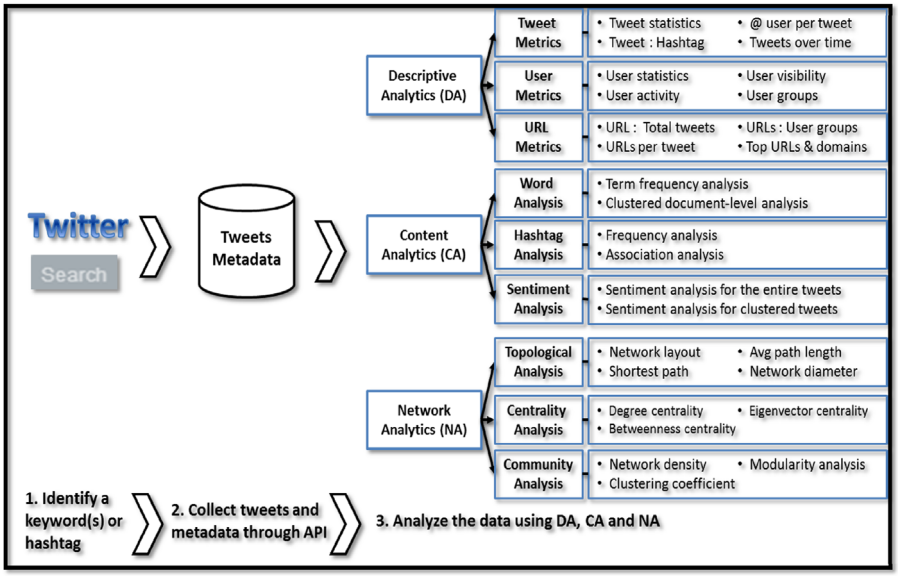

Fig. 1. A proposed framework of extracting intelligence from Twitter (Twitter Analytics).

While word and hashtag analyses focus on finding facts in the tweet content, finally, sentiment analysis (or opinion mining) is primarily interested in extracting subjective information (e.g., emotion, opinions) in tweets (Feldman, 2013; Pang and Lee, 2008). Sentiment analysis can be performed at two levels: (1) the entire tweets; and (2) several clusters of tweets in terms of themes. The task is to classify each tweet as negative, neutral, or positive. The above tweet about supply chain and Bangladeshi workers is an example of tweets with negative sentiment. Thus, analysis of the entire tweet data can reveal the overall sentiment of a keyword or a hashtag. Also, it is possible to identify different clusters of tweets in terms of themes. Tweets with #supplychain can be further clustered into sub-groups. Sentiment analysis can be conducted for each cluster of tweets. There are different techniques and tools for sentiment analysis (Pang and Lee, 2008). Thus, for high analysis accuracy, the choice of sentiment analysis technique/tool should be made carefully, while considering the key characteristic of a tweet, which is short and informal.

3.3. Network analytics (NA)

Twitter users engage through @reply and retweet. As a result, it is possible to extract network information from Twitter data using the techniques and metrics in network theory, which is increasingly used in many academic disciplines (Burt et al., 2013), including SCM (Borgatti and Lin, 2009; Carter et al., 2007; Galaskiewicz, 2011; Kim et al., 2011). Nodes (e.g., Twitter users) and edges (e.g., relationships) are two basic terms in the theory. Network topology refers to a layout of the nodes and the edges based on the information of reply and retweet in Twitter. This network visualization uncovers patterns in interactions among users. Various network metrics (e.g., average path length) provide the detailed description of such a network. Using Twitter data, there could be two kinds of topological network: friendship network and @reply (or mention) network. Friendship networks can be constructed based on the information of follower and following. Also, the conversation using @reply creates interpersonal relationships among Twitter users.

In addition, network theory offers centrality analysis, which uses node-level metrics, such as degree and betweenness centrality, revealing influential actors in the network. Degree centrality, a key metric, explains who has the most ties (or degrees) to others in the network (Wasserman and Faust, 2005). While degree centrality focuses on those nodes adjacent to a focal node, "betweenness centrality" includes distant paths of the focal node. While centrality analysis mainly focuses on individual nodes (or users in Twitter), community analysis explores network-level characteristics. For example, network density represents the portion of all possible connections between nodes, and, thus, it is a measure of network cohesion (Wasserman and Faust, 2005). Modularity is a measure of how strongly the network is divided into modules. Modularity analysis identifies specific communities from the network through visualization.

In addition to these analyses and metrics, there is a myriad of network concepts, analyses, and metrics. Thus, a well-framed research question can be helpful for selecting a manageable list of analyses and metrics when using descriptive analytics (DA). Proper changes in analysis techniques and metrics should be made for other social media data. For example, Facebook data enables the layout of different networks (e.g., personal, group, fan page, timeline).

4. Research method

The ideal approach to demonstrate the proposed framework and to gain insights into the use and potential role of Twitter in supply chain contexts, is to collect the entire Twitter data for a certain period and extract relevant intelligence. However, given the vast amount of Twitter data (about 500 million tweets per day), all studies using Twitter data need a data sampling process, which relies on hashtags and/or keywords to identify relevant information. To collect tweets discussing supply chain-related topics and events from Twitter, we initially conducted a series of key word and hashtag searches, including "supply chain", "SCM", "logistics", "supply chain management", and so on. This led us to find out that #supplychain is the most prevalent hashtag used by supply chain professionals and organizations. Our formal data collection was conducted between February 5 and April 10, 2013. The final dataset includes 22,399 tweets with the hashtag #supplychain and their metadata.

4.1. Descriptive analytics (DA)

Descriptive analytics of Twitter (and social media) data is considered one of the key areas of interest for businesses and

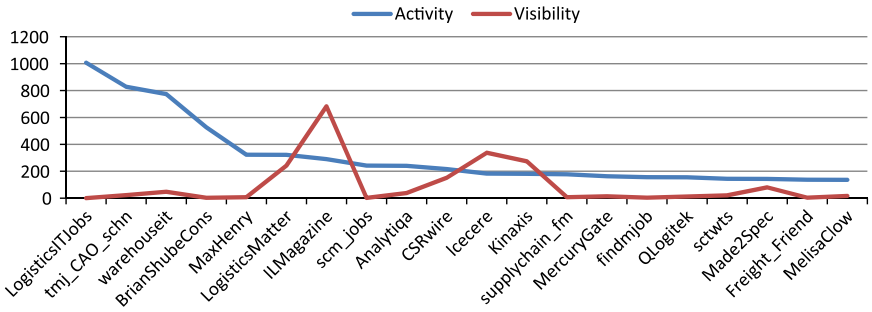

Fig. 2. Most active users vs. most visible users.

Table 1
Detailed word analyses in clustered documents.

Logistics	fre	Sustainability	fre	Manufacturing	fre	Risk	fre	Software	fre
logistics	2551	sustainable	118	manufacturing	835	risk	536	mobile	103
jobs	1070	csr	61	risk	206	execs	193	android	96
careers	1014	food	29	reshoring	196	manufacturing	182	cyber	90
freight	262	csrwire	32	sourcing	149	part	125	portal	84
software	251	improving	36	part	128	planning	123	tracking	78
trucking	242	greenbiz	32	strategic	127	strategic	122	socialmedia	70
transportation	165	green	29	planning	124	deloitte	102	routes	66
shippers	112	procurement	27	mfgexecutive	116	risks	110	optimize	55
logisticsviewpt	96	ecodesk	27	ajsweatt	115	mfgexecutive	107	app	44

researchers. There are companies (e.g., twitonomy) with commercial application services, which offer some descriptive metrics. To perform DA, we used script languages (Bruns and Burgess, 2011) and multiple statistical and data mining techniques. Script languages were needed to extract such information as users and hashtags from the dataset of tweets. Statistical and data mining techniques helped develop and visualize descriptive statistics.

Tweet statistics: Among 22,399 tweets, original tweets, retweets, and @replies account for 58% (12,920), 28% (6369), and 14% (3110), respectively. We found more than 3800 different hashtags in the tweets, ranging from popular SCM hashtags (e.g. #logistics, #manufacturing) to others, such as #slave and #telehealth. Over 16,000 tweets (70% of the tweets) contained more than 2 hashtags, indicating that the majority of tweets are intersecting multiple areas of interest. For example, tweets contain two or more hashtags: #supplychain, #CSR (corporate social responsibility), and #ethics. An example is "Too often, companies do NOT know the source of materials in their supply chain #CSR #Ethics #supplychain".

User analysis: We found 4313 unique users in the dataset. This means each user sends out, on average, 5.19 tweets: 3 original tweets, 1.48 retweets, and 0.71 @replies per user. Active users are calculated based on the number of tweets (original tweets + retweets + @replies). The visibility of users can be calculated by the number of @replies received (=@replies received + retweets received) (Bruns and Burgess, 2011). Fig. 2 shows the most active users and the most visible users: the most active users are not necessarily the most visible users. We also visualized the activity of most visible users. The result suggests that highly visible users tend to be active users as well. Major logistics providers (e.g., UPS), manufacturers (e.g., Unilever), and retailers have Twitter accounts. They are visible but not active in our data because most of their tweets may not contain #supplychain.

URL analysis: URLs are popular in tweets. 89% (19,890) of the total tweets contained one or more URLs. 11,362 different URLs were found from these tweets. Especially active and visible users include URLs in their tweets: almost all tweets from those users contain at least one URL. Top URLs include companies' webpages, SCM online newspaper sites, and articles about manufacturing leadership and big data. Top URL domains include http://www.tweetmyjobs.com (job announcements), http://www.linkedin.com, http://news.google.com, https://community.kinaxis.com, http://paper.li (SCM online magazine), http://www.ebnonline.com (SCM online magazine), http://www.csrwire.com (news related to corporate social responsibility), http://www.analytiqa.com (business intelligence company), http://www.industryweek.com, http://www.scmr.com (supply chain management review), and http://www.inboundlogistics.com (logistics magazine), among others.

4.2. Content analytics (CA)

CA involved three types of analysis: word analysis, hashtag analysis, and sentiment analysis. Word analysis further included term frequency analysis and clustered document-level analysis. Hashtag analysis was based on hashtag frequency analysis and association analysis of different hashtags. Finally, sentiment analysis was conducted at two levels: the subjectivity of (1) the entire tweets, and (2) those categorized or clustered tweets according to five top themes (CSR, Risk, Logistics, Manufacturing, and IT). CA relied on natural language processing (NLP) techniques, association algorithms, document clustering techniques, and opinion mining. Detailed discussions of these topics can be found in the NLP and sentiment analysis literature (Bird et al., 2009; Feldman, 2013; Manning et al., 2008; Pang and Lee, 2008).

Word analysis: Most popular words in tweets were logistics (found in 3961 tweets), jobs (3874), manufacturing (1309), careers (1160), risk (744), procurement (719), warehouse (614), software (605), sustainability (602), import (549), export (544), freight (526), sourcing (525), global (515), operations (503), retail (470), cloud (314), data (276), re-shoring (276), visibility (238), and security (219), among others. We further clustered the tweets in terms of five popular themes – logistics, sustainability, manufacturing, risk, and software – in the dataset, and then conducted word analysis. The detailed findings are shown in Table 1.

Hashtag analysis: 3839 different hashtags were found in the tweets and they appear 62,575 times. The most popular hashtags include #supplychain, #jobs, #tweetjobs, #logistics, #careers, #manufacturing, #sustainability, #export, #import, #brianshube, #procurement, #equity, #manufacturing, #csr, #mobile, #3PL, #freight, #sourcing, #Android, #IT, #trucking, and

#distribution, among others. Two hashtags were most common in the tweets. On average, there were 2.79 hashtags per tweet. This warrants association analysis among hashtags. The analysis shows that the items (#logistics and #supplychain) are most popular, appearing in 5.6% (1254 tweets) of the total tweets (22,399).

Sentiment analysis: There are different tools and algorithms for sentiment analysis. We chose SentiStrength because the sentiment analysis algorithm is designed for informal texts such as tweets (Thelwall et al., 2011). Fig. 3 shows the sentiments at the entire dataset level. Many tweets appear to be neutral (neither positive nor negative), as indicated by a high portion (67%) of tweets with the score 0. Another large portion (28%) of tweets scores either −1 or +1, which is relatively neutral. However, some tweets contain either strongly negative or positive sentiment. Table 2 shows some exemplar tweets with relatively strong sentiments.

Next, we separated the tweets into five clusters, using such themes as CSR, Risk, Logistics, Manufacturing, and IT. The outcome is introduced in Fig. 4. The pattern that emerged from the sentiment analysis of these five clusters of tweets is also a bell-curve shape. Risk-related tweets appear to be more negative than the other groups of tweets.

Table 3 shows exemplar negative and positive tweets from each group. For instance, a negative risk-related tweet ("With new #supplychain controls in place IKEA meatballs back after horse-meat scare http://t.co/YKvYT1ov1H#ris") is referring to an article published in the business section of the Chicago Tribune, which describes the incident of horsemeat being found in the meatballs from Ikea's main supplier, Familjen Dafgård in Sweden.

4.3. Network analytics (NA)

Topological analysis: A large social network was constructed including 5447 nodes and 9238 edges. In this network graph, the nodes are those users who either sent out or received @reply. The edges are the relationships between those users through @reply. The path length of most nodes is between 3 and 8. The network diameter is found to be 19, which is the longest path between two nodes in the network. The typology (Fig. 5) indicates that it is a large and sparse network. Despite this, the average path length is 5.82, indicating that, on average, everyone is about six nodes away from each other. This seems to be due to a number of popular nodes (or hubs) connecting different groups of nodes, which are sparse (Galaskiewicz, 2011; Watts, 2003).

Centrality analysis (*node-level metrics*): Among a few node-level network metrics, in-degree is a simple measure of a node's connectedness with others and can be an indicator of a user's popularity. Companies (e.g., @deloitte, @toyotaequipment) and industry presses (e.g., @ILmagazine) in the SCM field draw many replies or mentions, as indicated by their high in-degree values. Some individual users (e.g., @Lcecere) are noticeable. In addition, many users mention CSR-related industry presses (e.g., @GuardianSustBiz, @CSRwire) and individuals (e.g., @AmanSinghCSR) in their tweets (Table 4).

Many of those with high connections are shown to be in communication paths among other users. For example, @kinaxis, a SCM IT solution company, is in connection paths between some hubs, including @Ilmagazine, @Lcecere, etc. Looking at the network closely reveals that these tend to be key hubs in their communities of nodes. For example, @logisticsmatter is a hub node in a community of users interested in logistics, and @GuardianSustBiz and @schwild are in communication paths between users discussing CSR and related topics. While centrality is low, supply chain companies, including logistic providers (e.g., @UPS), manufacturers (e.g., @unilever), and retailers (e.g., @walmart) are present in the dataset.

Community analysis (*network-level metrics*): The community analysis shows a very low graph density (0.001), indicating that the entire #supplychain network is sparsely distributed (not cohesive), as shown in Fig. 5. This may be an indication that there are many dispersed groups in the network. We used a community detection method (Blondel et al., 2008), embedded in Gephi, an open source graph software tool. This method reveals over 400 communities in the #supplychain network. The majority of these communities are quite small-scale. There are four large communities, each of which represents over 5% of the total nodes, about corporate social responsibility, sustainability, manufacturing, and SCM software. The largest community is a community of CSR and sustainability, which represents 8% of the total users. The second

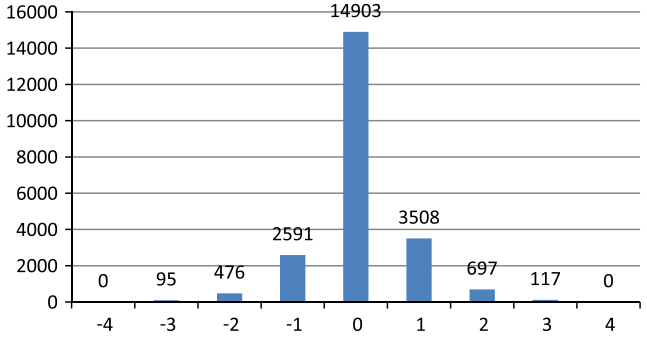

Fig. 3. Sentiment analysis at the entire dataset level (the numbers on *x*-axis indicate the degree of either positive or negative sensitivity).

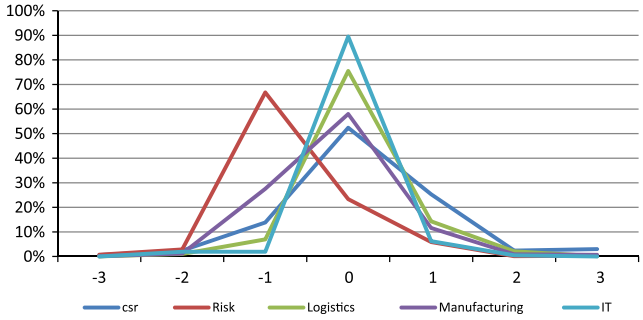

Fig. 4. Sentiment analysis of the clustered tweets (CSR, IT, Manufacturing, Logistics, Risk).

Table 2
Exemplar tweets with relatively strong sentiment.

Exemplar tweets	Sentiment
This development is pretty exciting for me #supplychain #sustainability	3 (positive)
Samsung assures excellent working conditions in China. ⟨http://t.co/9VcBIL1XAj #workingconditions #supplychain #responsiblesourcing #rtw⟩	3 (positive)
Loving the feedback that I am getting on this report today! #supplychain ⟨http://t.co/7DJaJFFl⟩	3 (positive)
As parked 787 s multiply? Boeing cash drain worries grow ⟨http://t.co/up6V9sBYbi #supplychain⟩	−3 (negative)
CHaINA Magazine: Apple Finds Child Labor Abuses in Its Supply Chain – As the controversy regarding. ⟨http://t.co/kt6MMXvng #SupplyChain⟩	−3 (negative)
Walmart US Chief Says Sales are Suffering Because of Restocking Issues ⟨http://t.co/xhpK4pYy3v #supplychain⟩	−3 (negative)

Table 3
Exemplar tweets from five clusters of tweets.

	Exemplar tweets	Sentiment
CSR	Investigation of #Apple #SupplyChain by #SACOM reveals continued #labor abuse throughout despite Apple's claims. ⟨http://t.co/Cm0VYeTT94 #CSR⟩	Negative
	Loving this Green Supply Chain infographic ⟨http://t.co/M0spSUs6WG #supplychain #CSR #infographic @SCInsightsLLC⟩	Positive
IT	Supply Chain Disruption a Major Threat to Business from @forbes ⟨http://t.co/raX48u4Zcw #supplychain #IT #analytics⟩	Negative
	How @Sony strengthened its supply chain and added value ⟨http://t.co/B0DTiWPAnm #GrnBz via @GreenBiz #IT #supplychain⟩	Positive
Logistics	Could I expect to receive my parcel today? I doubt it. Another terrible experience from @Parcel2Go #expensive #supplychain #logistics	Negative
	Great day @ #DalhousieUniversity! Excellent case study presentations by 16 teams. Join Careers in Motion @JDIcareers #logistics #supplychain	Positive
Manufacturing	Central China province suffers post-Spring Festival #labor shortage #manufacturing #SupplyChain #reshoring ⟨http://t.co/fX09sxmlxN⟩	Negative
	Excellent insights: Predictions from #SupplyChain Gurus for 2103. ⟨http://t.co/MQFZSgTI (See #manufacturing at end)	Positive
Risk	With new #supplychain controls in place IKEA meatballs back after horsemeat scare ⟨http://t.co/YKvYT1ov1H #risk⟩	Negative
	Thanks! RT @riskleadership @GenexLogistics @Kinaxis: #SupplyChain Excellence in Words and Numbers by @indexgirl ⟨http://t.co/9gV2cXD2⟩	Positive

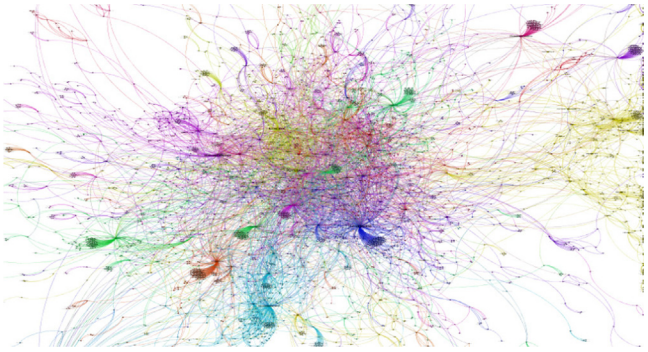

Fig. 5. The topology of "the supply chain sphere" in Twitter.

Table 4
High in-degree users.

User	In-degree	Out-degree	Degree
llmagazine	221	57	278
logisticsmatter	142	6	148
industryweek	127	0	127
deloitte	108	6	114
mfgexecutive	103	1	104
CSRwire	95	26	121
Lcecere	80	57	137
GuardianSustBiz	79	16	95
ajsweatt	79	25	104
toyotaequipment	76	111	187
logisticsviewpt	75	9	84
SustainBrands	72	8	80
Kinaxis	59	45	104
sdcexec	59	0	59
SCDigest	54	0	54

largest community is focusing on manufacturing and distribution. 5% of the total users belong to this community. The SCM software community includes another 5% of users.

5. Discussion

In this section, we discuss our findings in light of those four questions raised in the introduction. This discussion will also serve as the basis for Section 6.

5.1. What are the characteristics of supply chain tweets? Are there any patterns of communication and information diffusion?

There are different reasons for individual and organizational users' tweeting. Twitter users disseminate information using URLs, chat about daily routines, engage in conversation with @reply, and report news about events and incidents (Java et al., 2007). In a random sample of tweets, the rate of retweet is just 3%, and 22% of tweets contain a URL (Boyd et al., 2010). In contrast, 89% of #supplychain tweets include a URL and 28% of them are retweets. Also, the other 16% of tweets contain @user, meaning these tweets are mentioning one or more other users. Overall, this indicates that supply chain tweets appear to be more conversational and engaging than random samples of tweets. Supply chain professionals and organizations use Twitter for reporting news and for information sharing. About 12% of randomly selected tweets contain a conversation (@reply) (Java et al., 2007). This rate is slightly lower than that of #supplychain tweets (14%), indicating that #supplychain tweets appears to be more conversational than public tweets.

The rate of hashtags in #supplychain tweets also draws attention. Users include hashtags to indicate that their tweets are topical, so other users with similar interests can follow. While it is not clear how many randomly sampled tweets would contain at least one hashtag, we expect a relatively low percentage. Only 13–23% of tweets by software engineers, for instance, contain at least one hashtag (Bougie et al., 2011). In constrast, a large portion (73%) of #supplychain tweets appear to contain two or more hashtags. On average, almost 3 hashtags appear in tweets. In addition, there is a surprisingly large number of hashtags (3839) found in #supplychain tweets. Among those topics, logistics, manufacturing, sustainability, corporate social responsibility (CSR), risk management, and IT account for a large portion of the total number of tweets.

We found that two factors play a key role in determining information diffusion of supply chain tweets. First, tweets about timely issues and challenges tend to be more widely diffused than others. This is evident in that a disproportionately large number of tweets containing such hashtags as #manufacturing, #sourcing, #reshoring, #procurement, #retail, #sustainability, #CSR, #risk, #BigData, #SocialMedia, and #food are widely diffused through retweeting. In contrast, job-related tweets are rarely retweeted. This shows that tweets concerning new trends (e.g., #BigData) and issues (#risk, #sustainability, #manufacturing) in SCM are propagated widely. Second, the number of hashtags is positively associated with the degree of diffusion through retweets. We further examined those top retweeted tweets. The result shows that those tweets widely diffused through retweets tend to contain six hashtags on average,

which is twice that of other less popular tweets. Our findings are partially alinged with studies of Twitter data in other fields (Stieglitz and Dang-Xuan, 2013; Suh et al., 2010; Yuan et al., 2012). These studies also suggested other potential factors for information diffusion, such as the number of followers and following (Suh et al., 2010), and the degree of tweet sentiment (Stieglitz and Dang-Xuan, 2013).

5.2. What supply chain topics or contents are shared in Twitter? Are there any prevalent topics or contents?

Supply chain topics are very diverse, as evidenced by the number of hashtags (3839) in the data. Most popular hashtags appear to be similar to topic areas covered in academic SCM journals. They include #manufacturing, #logistics, #sustainability, #procurement, #csr, #3PL, #sourcing, #IT, #distribution, #transportation, #risk, #healthcare, #ERP, #riskmanagement, #innovation, #purchasing, #lean, and #inventory. A close examination also indicates that topics of interest in tweets are broader than what we generally discuss about SCM in academic press. They include #BigData, #SocialMedia, #careers, #equity, #CRM, #SaaS, #humanrights, #horsemeat, #fashion, #RFID, #fairtrade, #ClimateChange, #Android, #ethics, #analytics, and #humantrafficking.

One noticeable hashtag is #humanrights. On April 24, 2013, there was a deadly garment factory accident[4] in Bangladesh, which has led to a great deal of discussion of SCM, with topics such as #safety, #consumergoods, #csr, #sustainability, #ethics, and #humanrights in social media, particularly in Twitter, and the academic press. Our data collection was finished before this accident. Despite this, our data also contain numerous tweets about #humanrights and #supplychain. First, some of these tweets remind Twitter users of another previous garment factory accident, also in Bangladesh, in November 2012 ("#Bangladesh factory fires – the hidden dangers of subcontracting. http://t.co/taEDvIwZ #supplychain #labour"). Some also discuss supply chain strategy at such events ("What is #Walmart's long-term sourcing strategy in Bangladesh? http://t.co/Wuv1I4TjkR #supplychain #humanrights"). Others warn of another accident in Bangladesh and elsewhere ("Bangladesh fires reinforce pressing need for greater #supplychain transparency http://t.co/HYdCfkIoiu").

The analysis of words shows that wording in the entire tweets is similar to that of hashtags. However, the word analysis of clustered documents shows that there are distinctive words used in clustered tweets. Logistics is the most popular word in tweets. The tweets about logistics include such words as careers, software, trucking, freight, transportation, and shippers. In contrast, the tweets about sustainability include such words as csr, food, csrwire, improving, and green. Popular URL domains seem to coincide with the analysis of hashtags and words. They are related to careers and jobs, SCM news outlets, and SCM IT companies. The diversity of supply chain topics is also evident in the findings of over 400 communities from network analytics. Noticeably, corporate social responsibility, sustainability, manufacturing, SCM software, and logistics represent some of the largest topical communities. Many small communities represent groups of other SCM topics.

5.3. What are the characteristics of those Twitter users who are discussing supply chain topics?

Our analysis reveals important information regarding who is active in Twitter. Some of the most active users are job or career services. Nearly all tweets from this group of users are original tweets, which are job announcements for supply chain and logistics companies. A second group includes SCM practitioners. Another active group includes SCM magazines, IT service companies (e.g., @Analytiqa, @Kinaxis), and news service companies (or aggregators) (e.g., @logisticsmatter, @CSRwire, and @supplychain_fm). Not all active users are highly visible. Visible users receive many @reply (or mentions) and their tweets are retweeted. Highly visible users come from diverse areas (e.g., CSR, manufacturing) and roles (e.g., SCM experts, online magazines, professional organizations, and IT companies). Some major logistic providers (e.g., UPS), manufacturers (e.g., Unilever, Sony), and retailers (e.g., Walmart) are visible, but most of them are not very active in #supplychain tweets. This seems to be because these large carriers' and manufacturers' Twitter accounts tend to be used to send promotional messages to their followers, as part of a brand management strategy, rather than engage with their business partners and clients in SCM contexts.

The analysis also shows that a relatively small percentage of users account for a large portion of tweets. For example, an analysis of over 11 million tweets found that only 5% of users account for 75% of tweets (Cheng et al., 2009). A random sample of 300,000 tweets also shows that 10% of users account for over 90% of tweets (Heil and Piskorski, 2009). This pattern appears very strong in #supplychain tweets. Only 1% (45 users) and next top 9% (395 users) account for almost 40% and 34% of tweets, respectively. This is more evident in the ratio of users and original tweets. The top 10% of users account for 52% and 33% of original tweets. However, the other 90% of users account for a large portion (50%) of retweets, indicating this group of users tend to be followers of those highly visible users in the network.

5.4. What are the sentiments of supply chain tweets? What types of supply chain tweets tend to contain sentiment?

#supplychain tweets contain relatively low sentiment. While this finding was initially surprising, the findings from descriptive analytics (DA) and content analytics (CA) help explain why. Unlike those tweets, either for or against certain political candidates and movies, most #supplychain tweets were about events, SCM news and reports, jobs, and advertisements. Thus, those tweets tend to contain weak sentiment. Another explanation would be that there was no major SCM-related incident during the period of data collection. Major events, such as the Bangladesh garment factory collapse, draw emotional, largely negative, tweets. Nevertheless, some tweets were found to be carrying strong disappointments about a company's delivery service, sales performance, and ethical (or environmental) standards, and risk and disruption in the supply chain.

Exemplar tweets are "Nine Retailers with the Worst Customer Service - 24/7 Wall St. http://t.co/BcBZ63meXs #business #supplychain #manufacturing #logistics", "Investigation of #Apple #SupplyChain by #SACOM reveals continued #labor abuse throughout despite Apple's claims. http://t.co/Cm0VYeTT94 #CSR", and "Central China province suffers post-Spring Festival #labor shortage #manufacturing #SupplyChain #reshoring http://t.co/fX09sxmlxN". Positive sentiment was found in promotional tweets ("How @Sony strengthened its supply chain and added value http://t.co/B0DTiWPAnm #GrnBz via @GreenBiz #IT #supplychain"; "Great day @ #DalhousieUniversity! Excellent case study presentations by 16 teams. Join Careers in Motion @JDIcareers #logistics #supplychain").

Among the tweets, those related to supply chain risk, manufacturing, and CSR are considered more sentimental than others (IT, logistics). Noticeably, risk-related tweets tend to carry far more negative sentiment than those of other topics. There appear to be disproportionately more negative tweets in the topic of manufacturing. Exemplar tweets are "Quality of #manufacturing and #supplychain #education is a growing concern http://t.co/jfswNukNH",

[4] This incident occurred on April 24, 2013, which is right after our formal data collection was completed.

Table 5
Twitter's potential role for supply chain professionals and companies.

	Examples
Professional use	
Learning	• Following experts on the topics such as supply chain analytics • Searching topics (or keywords)
Promoting	• Tweeting/retweeting useful information and opinions on timely topics and issues
Networking	• Using such Twitter features as @reply and follower/following
Organizational use	
Stakeholder engagement	• Twitter as a communication platform • Spreading positive images as socially responsible and successful companies • Reaching out to a large public with success story through tweets and retweets
Hiring	• Twitter as a hiring tool • Tweeting job openings and descriptions • Mining Twitter user timeline and identifying talented professionals using descriptive, content, and network analytics
Demand shaping and sales	• Twitter as a sales channel • Tweeting production information and encouraging followers to retweet • Creating customer demands by tweeting coupons and discounts
Market sensing and new product/service development	• Twitter as a market sensor • Extracting demand signals from customers and markets using sentiment analysis • Getting customers' ideas and feedback about products, quality, and service
Risk management	• Twitter as an event monitoring and collaboration tool • Sensing supply-chain related events, disruptions, and other news in real time • Broadcasting supply chain events and risks in real time to supply chain partners and helping collaboration

"Supply chain risk on the rise http://t.co/cMeWWotx #manufacturing #SupplyChain" and "#FastFashion retailer #Zara Faces #Slave-Labor Allegations. Again http://t.co/nTJWxjzus3 via @ecouterre #CSR #manufacturing #supplychain". "Bad news tends to travel fast" (Naveed et al., 2011). This may explain the proportionately high diffusion rate of those tweets with #manufacturing and #risk.

6. Implications: the use and potential role of Twitter for supply chain practice and research

Derived from the proposed analytical framework in Section 3, its application in Section 4, and the research findings in Section 5, below we present further implications of Twitter for professional use, organizational use, and academic research. A summary is presented in Table 5.

6.1. *Professional use of Twitter*

Professionals in different fields have used Twitter for a variety of reasons (Conway et al., 2013; Vis, 2013). The findings of analyzing supply chain-related tweets indicate that they are more information-focused and conversational than regular tweets. This is evident from the inclusion of URLs and the degree of information diffusion through retweeting. These findings suggest that Twitter can be the platform for learning, promoting and networking, and some supply chain professionals are already taking advantage of Twitter for such activities.

First, learning is critical for the success of all professionals, but this is particularly true for supply chain professionals in a dynamic and fast changing business landscape. For them, Twitter is an important source of finding the latest news and events, and acquiring new knowledge about a broad range of supply chain topics and issues. Compared to traditional media (e.g., web pages, books, and conferences), the key characteristic of microblogging is that users do not need to be proactive in acquiring information. Twitter makes a large volume of information delivery/search and knowledge acquisition faster and more convenient, for example, by following experts on the topics and/or simply searching topics (or keywords). For example, the simple search[5] using "supply chain analytics" (c.f., Chae et al., 2014) at twitter.com provides opportunities for learning such a new topic through browsing relevant news, videos, and photos, and finding other professionals and organizations in this emerging area.

In addition, promoting one's expertise and networking with others is important in the professional world. Academics and journals use Twitter for promotion of their works and contents (Holmberg and Thelwall, 2014; Nason et al., 2014). Likewise, Twitter can be an effective tool for supply chain professionals to promote themselves, for example, through tweets/retweets of useful information and opinions on timely topics and issues. Examples are "Only 36% of #supplychain leaders use predictive modeling to forecast supplier risk and worst case scenarios http://t.co/mB3cxyuACU"; "I shared this with my workshop friends from today, so I wanted to share with you too. #supplychain http://t.co/9xqvZUa2MO". Unlike those traditional media that require significant time and effort to prepare contents for self-promotion and opinion sharing, in Twitter this can be accomplished by a short message including hashtags, URLs, videos, and/or photos. This "brevity" of microblogging explains the growth of tweets among professionals over the past several years. Also, such Twitter features as @reply and follower/following enable supply chain professionals to engage with other professionals and clients in real time

[5] https://twitter.com/search?q=supply%20chain%20analytics&src=typd&lang=en.

("@walmart is aiming to bring #women into their #supplychain, is it working? http://t.co/eG4LDK2Eec #IWD #womensday"; "Thx for sharing! MT @SCBrain: Great Resource! #SocialMedia in the #SupplyChain: http://t.co/UYKaCTPT87").

Supply chain professionals can take advantage of those analytical techniques and metrics in the proposed framework for learning, promoting, and networking. For example, the network analytical techniques and metrics can be utilized to figure out their networks and communication patterns for effective networking and promoting. Also, the descriptive analytics and metrics (e.g., number of replies and retweets) can indicate the popularity and reputation of professionals. Content analytics, especially sentiment analysis of the tweets mentioning them and the retweets, can enable professionals to measure how their tweets and opinions are perceived by other professionals and clients.

6.2. Organizational use of Twitter

The research findings from #supplychain tweets show that Twitter is currently widely used for stakeholder engagement, company promotion, and hiring.

Communication and stakeholder engagement: The data and content analytics show that, for some logistics providers, manufacturers, and retailers, the use of Twitter is strong in the area of stakeholder engagement. Especially, the focus has been on spreading their positive images as socially responsible and successful companies. For example, Unilever, a global consumer goods company ranked in Gartner's list of top supply chain companies, shows much interest in using Twitter for reaching out to a large public with their success story ("RT @2degreesnetwork: @Unilever is going for the top spot in #supplychain mgmt at the #2degreesAwards http://t.co/vHWODYXk1k RT @CSRwire"; "We're committed 2our #supplychain but we'll never lose sight of the value of embedding #sustainability 4our #brands http://t.co/OYr9M1jPVH"). Also, other companies such as DHL seem to use Twitter to increase public awareness of their brand and business activities (e.g., "RT @Analytiqa: DHL Supply Chain invests in Indonesia; increases in fleet, warehouse footprint, and staff #Logistics #SupplyChain").

This use of Twitter is expected since microblogging is about communication, and such features (e.g., brevity, fast updates, @reply, hashtag, retweet) of Twitter offer companies great opportunities to engage with a large number of stakeholders more quickly and conveniently than via traditional media. Communicating supply chain initiatives (e.g., sustainability) and positive news (e.g., innovation) with stakeholders is considered among the strategic uses of Twitter, since a message can be "viral" in Twitter or, at minimum, is viewed by followers. According to a report (Telegraph, 2012), the average number of followers per Twitter account is over 200. However, this number is very high for large corporations. For example, Unilever and UPS have 67,500 and 110,971 followers, respectively. This means Unilever's tweet is broadcast to a minimum of 67,500 followers, some of whom retweet. Currently, there is a severe imbalance between the number of following (about 4500 for both Unilever and UPS) and the number of followers, indicating the communication is likely unidirectional, rather than dialogic. Supply chain organizations should consider following more stakeholders for dialogic communication and engagement.

Hiring: As noted earlier in the research findings, another strong area of Twitter use is hiring. The data contain a large number of tweets about supply chain job opportunities, ranging from trucking to engineering. For example, General Mills, a food product manufacturer and Fortune 500 corporation, tweeted about a specific job "#Hiring: Plant Environmental Health and Safety Manager at our #Chanhassen, MN plant: http://t.co/3qMN2Y4r #supplychain #engineering #job". On the other hand, others try to draw potential job candidates to their career page, as Unilever does ("Interested in a #career in Supply Chain with #Unilever Learn more @ http://t.co/s8slqtNoNk #CPG #Jobs #Diversity #SupplyChain").

The role of competent professionals is critical for companies to stay competitive (Cottrill, 2010). As firms' supply chains are becoming global and more complex, hiring such people is a top priority for companies (Hohenstein et al., 2014). Social media emerges as a tool to recruit supply chain professionals (Fisher et al., 2014). Twitter can be used for both passive and active recruiting strategies. Passive recruiting is like tweeting job descriptions, as many companies in our dataset do. In addition, companies actively identify potential candidates or experts through analyzing user profile information and user timelines. The user profile of supply chain professionals includes their job experiences and other social media accounts and/or web pages for detailed profile information. Mining user timeline (e.g., tweets, retweets, following, photos/videos, favorites), using descriptive, content and network analytics, can offer valuable information, such as reputation, expertise, and professional network.

In addition to the currently popular uses of Twitter described above, there are other potential uses of Twitter by supply chain companies. They are demand shaping and sales, market sensing and new product/service development, and supply chain risk management, among others.

Demand shaping and sales: Twitter can be a channel for sales. In 2009, Dell announced it had made over $3 million in sales, since 2007, from those who visited their website directly from Twitter, during the time most companies had little understanding of using Twitter and other social media platforms (Miller, 2009). Twitter is suitable for reaching out to a large number of potential consumers, as companies tweet product information, coupons, and discounts, and this information appears in the followers' timelines. For example, Dell Outlet and Starbucks, among those recognized in the Gartner's list of top supply chain companies, have about 1,430,000 and 6,720,000 followers respectively. Some of these followers are likely to retweet coupons and discount information, which affect the purchasing decisions of their followers. Companies can even encourage retweeting to their followers through rewards (e.g., more discounts). The result is the increase in sales, as shown in some recent studies of tweets and corporate sales (Gong et al., 2014).

This Twitter effect on sales is due to what is broadly named "electronic word of mouth". Word of mouth is popularly recognized as a powerful mechanism, wherein consumers' decisions or opinions are spread to others and affect their purchasing decisions. Twitter increasingly plays the role of the platform for electronic word of mouth (Jansen and Zhang, 2009). The SCM field has long emphasized demand shaping as a best practice adopted by top supply chain organizations to balance supply and demand. Demand shaping is "a demand-driven, customer centric approach to supply chain planning and execution … influencing customer's demand towards products that the firm can supply easily and profitably" (Dietrich et al., 2012, p. 1). Companies can greatly increase their demand shaping capacity through strategically formulated tweets, which aim to create consumer demands. Using descriptive analytics (e.g., number of retweets), they can measure the effectiveness of their tweets for demand shaping and sales.

Market sensing and new product/service development: "Could I expect to receive my parcel today? I doubt it. Another terrible experience from @Parcel2Go #expensive #supplychain #logistics." In addition to its role as a sales channel, Twitter can be an effective "sensor", providing signals from customers and markets. The analysis of #supplychain tweets clearly indicates that tweets contain emotion, opinions, and preferences. This means Twitter has the potential to be a sensor platform. Market sensing is considered a dynamic capability significantly impacting the performance of organizations (Teece, 2007) by increasing traceability and tracking and understanding market demands (Beske et al., 2014). Twitter

data has been the source of successfully predicting customers' adoption of different types of products and services (Arias et al., 2014; Hennig-Thurau et al., 2014). The big data from Twitter and sentiment analysis (content analytics) can greatly help companies be effective in learning the public's perception of products (e.g., quality) and services (e.g., delivery) (O'Leary, 2011). This market-sensing data and analysis are critical for companies' sales and operations planning, which synchronizes market demand and supply capabilities (Tuomikangas and Kaipia, 2014), and can complement extant demand forecasting methods (e.g., smoothing) and processes used in practice (Ferbar et al., 2009).

In this vein, more companies are considering Twitter for getting customers' ideas and feedback about products, quality, and services. For example, Dell has used Twitter to respond to customer complaints and actively seek customer suggestions, as shown in the development of Dell Mini 10 based on Twitter users' complaints on Dell Mini 9 (Miller, 2009). Regarding Twitter use in this area, a Dell personnel notes "It's a great way to fix customer problems and hear what customers have to say, it's a great feedback forum … how can you miss?" (Miller, 2009). Customer knowledge is critical for successful product/service development (Chae, 2012). Starbucks uses Twitter and other social media by redefining the role of consumers from passive recipients to co-creators in product/service innovation process (Chua and Banerjee, 2013).

Risk management: "Helicopter hovering above Abbottabad at 1 AM (is a rare event)." This is a tweet by an IT consultant working late at night and unknowingly reporting the raid of terrorist Osama bin Laden hours before any news channels broke the news. A key characteristic of Twitter is the real time broadcasting of diverse events and accidents. Over 270 million users worldwide are potentially reporters or sensors (Sakaki et al., 2010) of events, such as disasters (e.g., Hurricane Sandy, Japan earthquakes), crises (e.g., Boston Marathon Bombing), and critical social changes (e.g., Arab Spring) (Hughes and Palen, 2009).

Supply chain risk management (SCRM) has emerged as a top priority for companies and a key stage of SCRM is detecting potential disruption (Chopra and Sodhi, 2014). Twitter, as the sensing and broadcasting platform, offers great opportunities for SCRM since tweets broadcast a variety of supply chain-related events, disruptions, and other news in real time. Examples are "Thailand braces for blackouts #supplychain http://t.co/WNmMoBM1Vr", "Honda recalls 250,000 vehicles globally http://t.co/f8E2PSvPxU #risk #riskmanagement #Insurance #marketing #supplychain" and "Strong earthquake sways buildings throughout Taiwan http://t.co/3i2SK7tw3L via @CTVNews #supplychain." Some tweets (e.g., "holy cow, I AM in Japan,… earthquake, earthquake right now!") may be created before such an earthquake is registered with the US Geographical Survey (Ostrow, 2009).

To respond to these potential risks, a supply chain needs to facilitate communication among supply chain personnel. Microblogging is suitable for instant communications and broadcasting them to a large population. "Dorsey's [co-founder of Twitter] genealogy of Twitter refers to communication systems for bicycle messengers, truck couriers, emergency services, ambulances, fire trucks and police" (Rogers, 2013, p. 1). There are a variety of supply chain-related events (e.g., road accidents, flood), which can cause supply chain risks and disruption (Tang and Nurmaya Musa, 2011). Twitter has the potential to be a communication system for logistics and transportation personnel to broadcast such events and risks in real time to the partners in their supply chain. This can help with supply chain risk detection and disruption recovery (Kumar and Havey, 2013; O'Leary, 2011).

6.3. Supply chain research

Aside from those implications for practical applications, important research implications can be derived. First, our findings related to the contents of tweets deserve further discussion. Almost 4 of 5 tweets include two or more hashtags and over 3800 hashtags are found in the Twitter data collected over a two month period. The variety of topics discussed with hashtag #supplychain is astonishing. This finding indicates that supply chain is relevant to a very large number of social practices (e.g., sustainability), and business and IT applications (e.g., big data). This variety in supply chain is also evident in other findings (e.g., a large and heterogeneous network topology, over 400 communities) from network analytics. Thus, these findings imply that the field of supply chain is shown to be as diverse as the number of hashtags and communities. This similar finding also appears in the academic research of "the intellectual structure of supply chain management discipline" (Giannakis, 2012). The citation-based research indicates that SCM is fundamentally interdisciplinary and there is much more diversion than cohesion in the field.

Second, among those many topics and interests, our findings from the analysis of words, hashtags, and communities show that sustainability and its relevant topics (e.g., corporate social responsibility, green management) have moved into the center of supply chain-related discussions in Twitter. This growth of sustainability-related discussions in social media is no different than academic research. Despite its relatively short history in academic research, the topic of sustainable supply chain management has become the mainstream research area (Chen et al., 2014; Giannakis, 2012; Seuring and Müller, 2008). Research communities can identify emerging supply chain topics and issues important to practitioners and companies from Twitter data.

Finally, the research design and findings show the possibility of using Twitter data for supply chain research. Researchers in diverse academic fields have used Twitter data for many important research questions. In contrast, there are few studies using Twitter (and social media platforms) in the SCM field. We believe that Twitter through API can offer SCM researchers (and industry practitioners) the opportunity to access not just open public data, but also "big data", which are significant in terms of scale, size, and speed. Social media in general and Twitter in particular, can serve as new data sources and collection methods, which could complement existing data sources and collection methods for SCM research and practice (c.f., Calantone and Vickery, 2010).

7. Limitations and future research

It is imperative for supply chain professionals and organizations (and even researchers) to effectively use social media platforms and social media data for their operations. However, the SCM field has been relatively slow in identifying the potential roles and uses of social media and social media data. Academic research and reported industry cases are rare on this important topic. This paper has responded to the current situation by proposing an analytical framework for Twitter data, highlighting a broad range of intelligence (e.g., popular topics, communication patterns, tweet sentiments), the extant use of Twitter in SCM contexts using the proposed framework, and finally developing further insights into innovative uses of Twitter for supply chain practice and research.

This study has limitations, particularly related to data collection. The first is the relatively short duration of data collection, which lasted a little over two months. Data collection for a longer period is expected to develop a more complete picture of the use of Twitter for SCM. Related to this is the way the data were collected. As noted earlier, we chose hashtag #supplychain to search and collect Twitter data. Another, perhaps better, approach would be using multiple keywords (e.g., supply chain) and/or hashtags (e.g., #manufacturing, #logistics) in data collection. This approach would enable research using a large quantity of supply chain-related Twitter data. Also, a

large volume of tweets, while they are useful for companies' supply chain decisions, may not contain such keywords as supplychain, manufacturing, logistics, risks, etc. A solution to remedy these cases is to acquire Twitter data using a large list of keywords.

We believe there is much need for enhancing our understanding of social media and social media data in supply chain contexts. At least two broad streams of academic research and practical applications should be followed. One area is developing detailed, practical guidelines, which can help companies in designing industry applications, using Twitter and other social media platforms, for diverse supply chain activities, including new product development, stakeholder engagement, supply chain risk management, and market sensing. Research programs partnering with innovative organizations can play important roles in this area. In this line, supply chain researchers should first study the innovative applications of social media in other disciplines. The other area is studying the impact of social media (and big data) investment (e.g., technologies, data scientists, and data repositories) on supply chain performance. This type of research is urgently needed, as there is increasing attention to and interest in big data and social media from industries and academia.

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