Intellectual Structure of Business Analytics in Information Systems

Full Paper

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Abstract

Business Analytics is arguably the most dominant topic of discussion among both academics and practitioners. As organizations scramble to derive insights from rapidly growing data, we see an exponential growth in the number of articles related to Business Analytics. The purpose of this article is to examine the conceptual foundations of the field of analytics based on an analysis of articles that have appeared in the IS senior scholars' basket of eight journals during the last 25 years (1992 - 2016). Using a combination of citation analysis and text mining, our study: (a) reveals the disciplines that influence Business Analytics research in information systems; and (b) explicates dominant themes latent in the corpus. Concepts related to Predictive Analytics, Business Intelligence, the Web, IT Management, Firm Performance and Decision Support were found to be at the heart of analytics research conducted by IS scholars in the basket of eight journals.

Keywords

Citation analyses, clustering, text mining, topic modelling.

Introduction

The exponential growth in data has prompted organizations to seek ways to gain a competitive advantage through analytics. Business Analytics (BA) promises to provide deep insights that can shape the strategic direction of firms, help them offer unique and personalized services to their customers, improve operational performance, and proactively detect anomalies (e.g., frauds) (Davenport, 2013). According to (Davenport, 2013), the evolutionary path to the enriched, data-driven products of today include Business Intelligence (BI) and Big Data. What is missing is an elucidation of the progression of ideas in BA. Of interest in this study is the conceptual foundation of BA that is latent in the research published in the IS senior scholar's basket of eight journals.

There is a long and rich tradition of research that has examined the intellectual structure of disciplines (Culnan, 1987; McCain, 1990). The primary aim of such studies is to trace the evolution of ideas from the past to the present and to anticipate forthcoming scholarship that will extend the boundaries of knowledge within a discipline. For instance, many IS researchers in the past have sought to understand the conceptual foundations of information systems (IS) in terms of how core concepts within IS have evolved and what its disciplinary status is (Grover, Gokhale, Lim, Coffey, & Ayyagari, 2006; White & Griffith, 1981, 1982; White & McCain, 1998). These studies relied on an analysis of citations to guide their investigation. Research typically used documents or authors as the units of analysis. It is not the document or author that is important, but the key concept they propagate (McCain, 1990). The fundamental premise of citation analysis is that frequently co-cited documents or articles are likely to be similar in their conceptual structure. Thus, the similarity matrix of co-citation frequencies can be subjected to quantitative analysis to draw insights into the evolution of thought within the field as well as to unravel its underlying intellectual structure.

Most of these studies endeavor to assess the progression of idea and/or explicate the prominent sub-fields

within a discipline (for example, see (Nerur, Rasheed, & Natarajan, 2008)). As mentioned earlier, citations that documents or authors give and receive provide the basis for understanding the key concepts disseminated in a corpus as well as for exploring ideational links.

While citations have proven to be very useful for detecting paradigm shifts (for example, see (Sircar, Nerur, & Mahapatra, 2001)) and for understanding how a discipline has evolved (e.g., (Culnan, 1987)), they suffer from some limitations (Zinkhan & Leigh, 1999). The foremost among the shortcomings is the fact that citations tend to ignore the context in which they occur within articles. Furthermore, the content of articles is completely disregarded when citations are used to delineate the intellectual structure of a field (Balijepally & Nerur, 2015). Finally, most citation studies focus only on seminal authors or documents, thus ignoring the contributions of many authors and/or articles (Zhao & Strotmann, 2007).

Recently, topic modelling has been used to identify the topics within a scientific discipline and analyze temporal evolution of those topics. For example, there is recent attempt at investigating how IS research topics relating with each other and how the evolution of topics has occurred in major IS journals (Hailiang Chen & Zhao, 2015). Similarly, (Wang, Bendle, Mai, & Cotte, 2015) reviews 40 years of Journal of Consumer Research and uses topic modelling to uncover key phrases, their relationships and evolution over time.

Text mining and topic modeling are getting increasingly sophisticated, and are eminently suitable for eliciting the thematic content of a corpus engendered by scholarship in a discipline. Indeed, citation analysis when combined with text mining can yield perspectives that neither one alone can provide. Therefore, our study employs both types of analyses to articulate the following:

- The reference disciplines that contribute to the existing corpus of knowledge on Business Analytics;
- The key words found in the corpus and their co-occurrence relationships;
- Clusters of related articles; and
- Dominant topics and their associated words.

It must be noted that the corpus of interest in our study comprises BA-related articles published in the IS senior scholars' basket of eight journals.

The remainder of the paper is structured as follows. The next section provides an overview of relevant literature, followed by a description of our methodology. Subsequently, we present our findings and conclude with a discussion on the implications of our study.

Methodology

The Web of Science database was used to retrieve abstracts and citation data related to business analytics articles published in the IS senior scholar's basket of eight journals[1] between the years 1992 and 2016. We used to the following keywords to formulate our query: "Business Analytics", "Business Intelligence", "Data Analytics", "Data Science", "Predictive Analytics", "Machine Learning", "Deep Learning" and "Analytics". This query resulted in 68 articles which were analyzed further[2].

Figure 1 shows the distribution of articles over the years. As can be seen from the figure, Information Systems Research (ISR) - with 17 publications - is the leading publisher of business analytics articles.

[1] IS senior scholar's Basket of eight journals https://aisnet.org/?SeniorScholarBasket?

[2] Due to page limits, we could not include citations for these 68 articles in the reference section

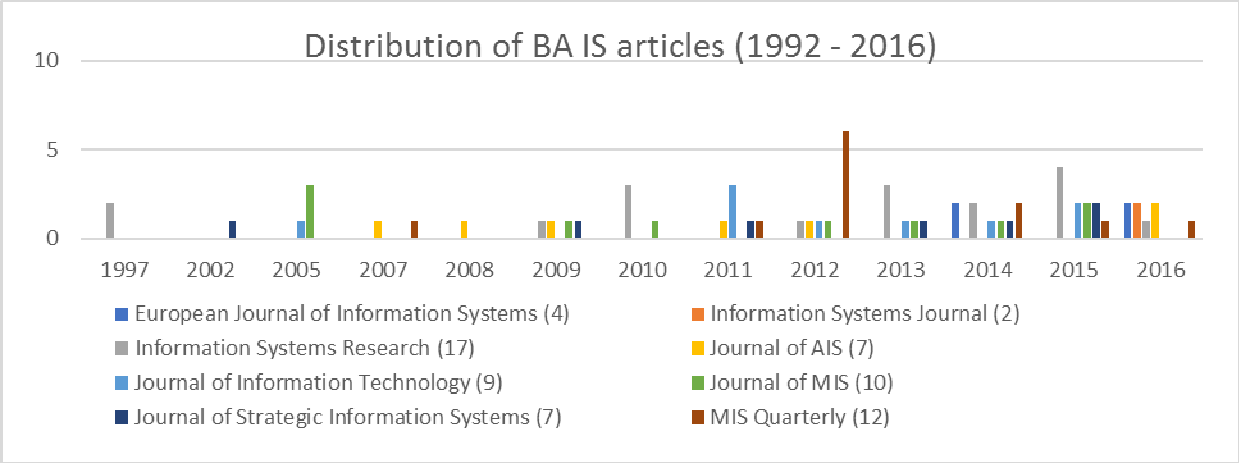

Figure 1: Distribution of BA IS articles by IS senior scholar's basket of eight journals over the last 25 years

Identifying the Reference Disciplines for BA IS research

The cited references from the 68 articles under consideration were analyzed to identify the reference disciplines that have contributed to BA-related research in IS. Out of the 5031 citations (i.e., references), 47 were not associated with any cited references, thus resulting in 4984 cited references in 2036 distinct publications with a mean of 73.3 cited references per article. Since our data is highly skewed with majority of cited references been cited just once over the period of 25 years, we removed all journals which were cited fewer than 10 times between 1992 and 2016. This step left us with 2151 citations for the 68 articles. To classify the list of cited references into reference disciplines we sought to be consistent with prior literature wherever possible (Agarwal, 2016; Grover et al., 2006). We also referred to a master-list of journals from Web of Science, which categorizes 11144 indexed journals into 22 disciplines.

The 11 referenced disciplines with important journal outlets is shown in Table 1 and the distribution in Figure 2:

Discipline	Journal name
Computer Science	Communications of ACM, IEEE Transactions on Knowledge Data Engineering, Machine Learning, IEEE Intelligent Systems, Artificial Intelligence, Journal of Machine Learning Research, Lecture Notes in Computer Science
Economics	American Economic Review, Quarterly Journal of Economics
General Business	Management Science, Harvard Business Review, Decision Science, Sloan Management Review, MIT Sloan Management Review, California Management Review
General Science	Science, Proceedings of the National Academy of Sciences
Information Systems	MIS Quarterly, Information Systems Research, Journal of Management Information Systems, Decision Support Systems, Journal of Strategic Information Systems, Journal of Information Technology, European Journal of Information Systems, Journal of Management Information Systems, Journal of Association of Information Systems, Information Management, Information Systems ,Information Systems Journal, Information & Management, Communications of Association of Information Systems, Information Systems Management, Journal of American Society of Information Science and Technology, ACM Transactions on Information Systems, Journal of American Society of

	Information Science, Business Intelligence, MIS Quarterly Executive, Expert Systems With Applications, International Journal of Information Management, Information Processing & Management
Marketing	Marketing Science, Journal of Marketing Research, Journal of Marketing, Journal of Academy of Marketing Science, Journal of Consumer Research
Operations Research / Operations Management	European Journal of Operations Research, Journal of Operations Management
Organization Science	Organization Science, Academic of Management Review, Strategic Management Journal, Academy of Management Journal, Administrative Science Quarterly, Journal of Management
Psychology	Journal of Personality and Social Psychology, Group Decision & Negotiation, Psychological Review
Sociology	American Journal of Sociology, American Sociological Review
Statistics	Statistical Science
Working papers	Not Available

Table 1: Disciplines cited by BA IS publications from the senior scholar's basket of eight

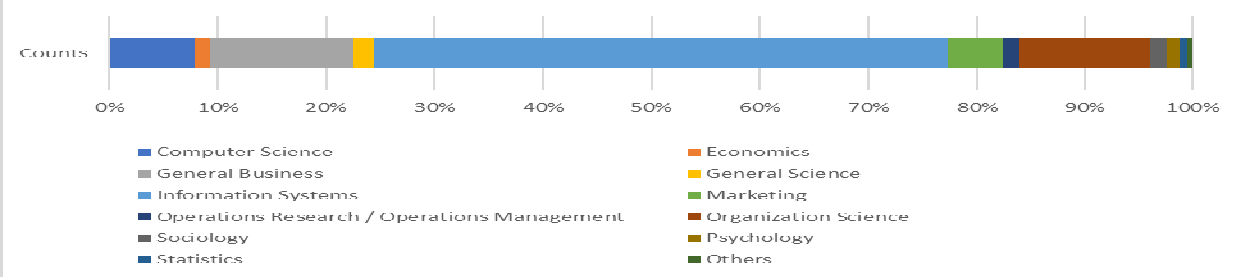

Figure 2: Proportions of referenced disciplines for BA IS articles published in IS senior scholars's basket of eight

As table 1 and figure 2 show, majority of articles cited information systems (1137 cited references) journals followed by general business, organization science and computer science journals with 284, 262 and 162 cited references respectively from a total of 2151 cited references. The distribution of cited references for journals belonging to the IS discipline is shown in Figure 3.

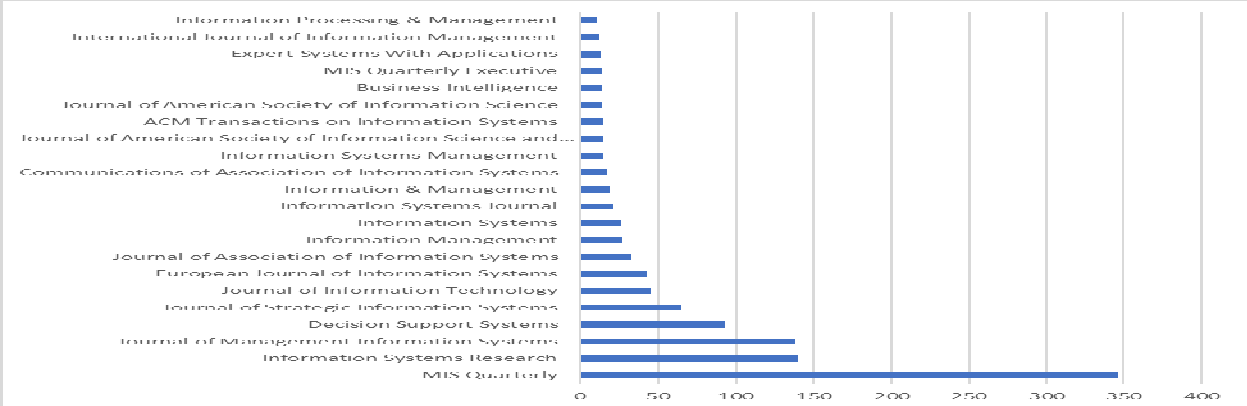

Figure 3 Distribution of IS journals referred by BA IS articles published in IS senior scholars basket of eight in the last 25 years

Clustering articles based on Bibliographic coupling

The concept of Bibliographic coupling is first proposed by (Kessler, 1963) where the similarity of documents is based on the similarity of references cited by these documents. That is, if two articles A and B cite the same article C, then A and B are said to be "bibliographically coupled" and are likely to bear some similarity in terms of the underlying theme or topic. The underlying themes shown in table 2 were obtained by performing bibliographic coupling using an excellent software called VOSviewer (Van Eck & Waltman, 2011; van Eck & Waltman, 2013).

Cluster No.	Articles	Underlying Themes
Cluster 1:	(Abbasi, Albrecht, Vance, & Hansen, 2012), (Bardhan, Oh, Zheng, & Kirksey, 2015), (Chellappa, Sambamurthy, & Saraf, 2010), (Clarke, 2016), (Fayard, Gkeredakis, & Levina, 2016), (Ghoshal, Menon, & Sarkar, 2015), (X.-B. Li & Sarkar, 2014), (Loebbecke & Picot, 2015), (Newell & Marabelli, 2015), (Pant & Sheng, 2015), (Raghunathan & Sarkar, 2016), (Shmueli & Koppius, 2011), (Zheng, Fader, & Padmanabhan, 2012)	Predictive analytics, Web, Crowd, Markets, Decision making.
Cluster 2:	(Baker, Jones, & Burkman, 2009), (Choudhary & Vithayathil, 2013) (Dong, Huang, Sinha, & Xu, 2014), (Greenwald, Kannan, & Krishnan, 2010), (Kayande, De Bruyn, Lilien, Rangaswamy, & van Bruggen, 2009), (Meyer et al., 2014), (Pant & Srinivasan, 2010), (Pant & Srinivasan, 2013), (Zhu, Prietula, & Hsu, 1997)	Predictive analytics, Decision support, Business processes, Data.
Cluster 3:	(Audzeyeva & Hudson, 2016), (Hsinchun Chen, Chiang, & Storey, 2012), (Chung, Chen, & Nunamaker Jr, 2005), (Deng & Chi, 2012), (Fan, Gordon, Pathak, & PATHAK, 2005), (Hu, Zhao, Hua, & Wong, 2012), (Shollo & Galliers, 2016)	Business intelligence, Web, IS Use.
Cluster 4:	(Abbasi et al., 2015), (Jabr, Mookerjee, Tan, & Mookerjee, 2013), (Lacity, Solomon, Yan, & Willcocks, 2011), (Xin Li, Chen, Zhang, Li, & Nunamaker, 2009), (Petrini & Pozzebon, 2009), (Sharma, Mithas, & Kankanhalli, 2014), (Susarla, Barua, & Whinston, 2010)	Business process outsourcing, Business and predictive analytics.
Cluster 5:	(D. Q. Chen, Preston, & Swink, 2015), (Coltman, Devinney, & Midgley, 2011), (Habjan, Andriopoulos, & Gotsi, 2014), (G. Kim, Shin, Kim, & Lee, 2011), (Xixi Li, Hsieh, & Rai, 2013), (Popovič, Hackney, Coelho, & Jaklič, 2014), (Wakefield, 2013)	Firm performance, IS Usage, SCM.
Cluster 6:	(Chau & Xu, 2012), (Constantiou & Kallinikos, 2015), (Gholami, Watson, Molla, Hasan, & Bjørn-Andersen, 2016), (Koh, Gunasekaran, & Goodman, 2011), (Lau, Liao, Wong, & Chiu, 2012), (Roussinov & Chau, 2008)	ERP, supply chain, Big data, Business intelligence.
Cluster 7:	(Abbasi, Sarker, & Chiang, 2016), (Agarwal & Dhar, 2014), (Müller, Junglas, vom Brocke, & Debortoli, 2016), (Park, Huh, Oh, & Han, 2012), (Provost, Martens, & Murray, 2015), (Sundararajan, Provost, Oestreicher-Singer, & Aral, 2013)	Information, Big data analytics, Privacy.
Cluster 8:	(Luftman & Zadeh, 2011), (Luftman et al., 2012), (Luftman et al., 2013), (Luftman et al., 2015)	IT management.
Cluster 9:	(Arnott & Pervan, 2005), (Arnott & Pervan, 2012), (Arnott & Pervan, 2014), (Rouibah & Ould-Ali, 2002)	Decision support systems.

Cluster 10:	(Clark, Jones, & Armstrong, 2007), (Mookerjee & Mannino, 1997), (Nelson, Todd, & Wixom, 2005)	Information, management support systems.
Cluster 11:	(H. M. Kim, Fox, & Sengupta, 2007)	Data models, Compliance.

Table 2 Clustered documents based on Bibliographic coupling and underlying themes

As we can see from Table 2, clusters 1, 2, 3 and 4 represents an overlapping theme with topics of Web, predictive analytics and business intelligence. Thus, this technique does not provide us with neat clusters with proper demarcation of boundaries between themes. Figure 4 represents the clustered documents based on the technique of bibliographic coupling using VOSviewer (Van Eck & Waltman, 2011; van Eck & Waltman, 2013).

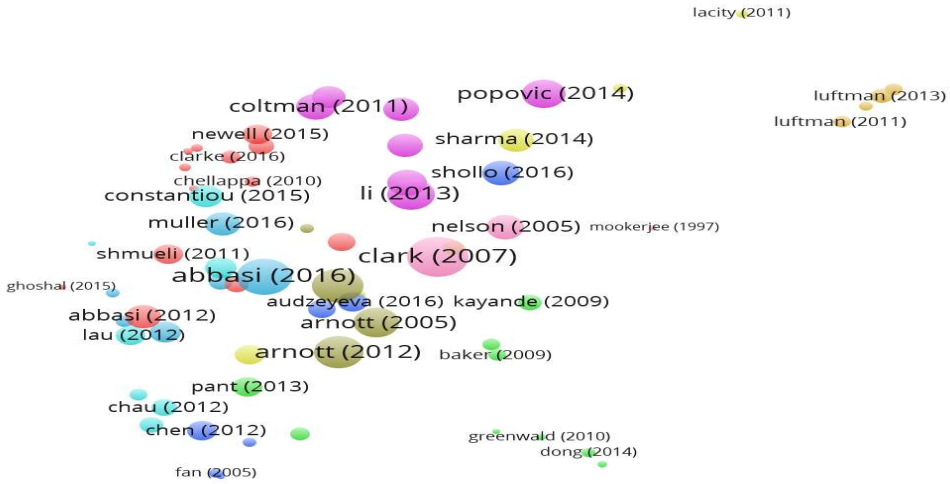

Figure 4 Clustering documents based on Bibliographic Coupling

Text Mining

The top 50 frequently occurring keywords are shown in Figure 5 with the word frequencies represented on the Y-axis. As expected some of the most frequently occurring words are information, data, business, DSS, intelligence, decision, support, analytics and analysis. Note that for text mining, cluster analyses and topic modelling, 66 articles are considered as 2 articles are editorials and does not contain abstracts.

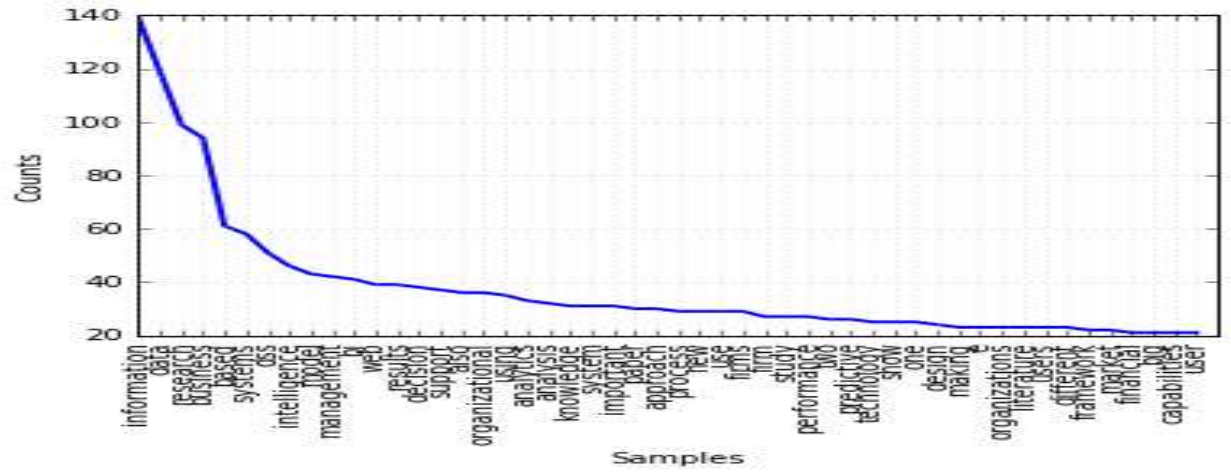

Figure 5 Distribution for frequently occurring words

Table 3 shows some of the frequently occurring keywords clustered together. The keywords are clustered together based on their frequency of co-occurrence (Van Eck & Waltman, 2011; van Eck & Waltman, 2013).

Cluster 1:	Approach, Big data, Challenge, Fact, Framework, Organization, Problem, Service, User, Web
Cluster 2:	Analysis, DSS, DSS Research, Journal, Practice, Research, System
Cluster 3:	Crowded Market, Firm, Market, Need
Cluster 4:	Model, Predictive Analytic, Role

Table 3 Clusters of frequently occurring key words based on their co-occurrence

Similarity of Documents Based on K – means Clustering

K – means clustering is a simple yet powerful unsupervised data mining technique for classifying a set of n data points into K clusters. Here, the data points within a cluster are closer in distance to the centroid of the cluster compared with the centroids of other clusters.

To determine the optimum number of K's, we followed a procedure outlined by (Mueller & Massaron, 2015). The K-Means clustering algorithm in "sklearn", a machine learning module in Python, was used for this purpose. The K-Means algorithm returns a measure called "inertia", which is essentially the aggregate of the difference between every data point and the centroid of the cluster to which it belongs. A smaller value of inertia suggests a more cohesive cluster. As suggested by (Mueller & Massaron, 2015), we plotted the rate of change of inertia against different values of K and chose the value of K corresponding to the one that caused the biggest "jump" in rate. Thus, 7 clusters were chosen for our analysis.

Cluster No.	Articles	Underlying Theme
Cluster 1:	(Chung et al., 2005) (Pant & Srinivasan, 2010) (Chellappa et al., 2010) (Shmueli & Koppius, 2011) (Zheng et al., 2012) (Abbasi et al., 2012) (Pant & Srinivasan, 2013) (Jabr et al., 2013) (Bardhan et al., 2015) (Pant & Sheng, 2015)	Web, Predictive Analytics.
Cluster 2:	(Nelson et al., 2005) (Greenwald et al., 2010) (Susarla et al., 2010) (Koh et al., 2011) (Chau & Xu, 2012) (Park et al., 2012) (Wakefield, 2013) (Xixi Li et al., 2013) (Habjan et al., 2014) (Dong et al., 2014) (Popovič et al., 2014) (Raghunathan & Sarkar, 2016)	Procurement, SaaS, Data warehousing, ERP, Importance of Information in an organization.
Cluster 3:	(Arnott & Pervan, 2005) (Clark et al., 2007) (Kayande et al., 2009) (Arnott & Pervan, 2012) (Arnott & Pervan, 2014)	Decision support systems.
Cluster 4:	(Rouibah & Ould-Ali, 2002) (Petrini & Pozzebon, 2009) (Hsinchun Chen et al., 2012) (Lau et al., 2012) (Audzeyeva & Hudson, 2016) (Shollo & Galliers, 2016) (Gholami et al., 2016)	Business intelligence.
Cluster 5:	(Mookerjee & Mannino, 1997) (Baker et al., 2009) (Deng & Chi, 2012) (Sundararajan et al., 2013) (Meyer et al., 2014) (Agarwal & Dhar, 2014) (X.-B. Li & Sarkar, 2014) (D. Q. Chen et al., 2015) (Constantiou & Kallinikos, 2015) (Newell & Marabelli, 2015) (Ghoshal et al., 2015) (Loebbecke & Picot, 2015) (Clarke, 2016) (Abbasi et al., 2016) (Fayard et al., 2016) (Müller et al., 2016)	Big data, Big data analytics, Decision making.
Cluster 6:	(H. M. Kim et al., 2007) (Xin Li et al., 2009) (Luftman & Zadeh, 2011) (Luftman et al., 2012) (Hu et al., 2012) (Choudhary & Vithayathil, 2013) (Luftman et al., 2013) (Provost et al., 2015) (Luftman et al., 2015)	IT management, Data sharing, Risks, Privacy.
Cluster 7:	(Zhu et al., 1997) (Fan et al., 2005) (Roussinov & Chau, 2008) (G. Kim et al., 2011) (Coltman et al., 2011) (Lacity et al., 2011) (Abbasi et al., 2015)	Firm performance, Business processes.

Table 4 Articles Clustered with K-means clustering and underlying themes.

Determining topics with topic modelling

Finally, we used Latent Dirichlet Allocation (LDA), as implemented in MALLET (Machine Learning for Language Toolkit)[3], to uncover 7 topics. The choice of 7 topics was to be consistent with the cluster analysis discussed earlier. The key topics, their associated words and the top five corresponding articles are shown in table 5.

Topic No.	Key Phrases	Top Five Articles	Underlying Theme
Topic 1:	information, web, status, pages, market, demand, recognition, mechanism, page, behavior, policy, revelation, show, crawlers, topical, products, link, sellers, locality, price	(Pant & Srinivasan, 2013) (Greenwald et al., 2010) (Dong et al., 2014) (Pant & Srinivasan, 2010) (Raghunathan & Sarkar, 2016)	Web, Predictive Analytics.
Topic 2:	predictive, firms, markets, analytics, ess, model, online, crowded, models, competitive, firm, find, explanatory, competing, performance, data, market, power, components, digital	(Chellappa et al., 2010) (Bardhan et al., 2015) (Shmueli & Koppius, 2011) (Pant & Sheng, 2015) (Zheng et al., 2012)	Predictive Analytics, Competitive Intelligence.
Topic 3:	Data, business, services, analytics, visual, rules, results, similar, privacy, quality, users, representations, facts, tasks, variety, made, context, theory, exploration, paper	(Baker et al., 2009) (Provost et al., 2015) (Newell & Marabelli, 2015) (Susarla et al., 2010), (H. M. Kim et al., 2007)	Privacy, Decision making.
Topic 4:	information, data, system, business, big, intelligence, research, organizational, study, organizations, bda, usage, based, systems, social, support, quality, strategic, framework, problems	(Xixi Li et al., 2013) (Fayard et al., 2016) (Popovič et al., 2014), (Deng & Chi, 2012) (D. Q. Chen et al., 2015)	IS Usage, Value creation.
Topic 5:	research, dss, systems, decision, model, support, design, analysis, bpo, empirical, business, science, major, making, management, information, published, decisions, journals, technology	(Arnott & Pervan, 2005) (Clark et al., 2007) (Kayande et al., 2009) (Arnott & Pervan, 2014), (Arnott & Pervan, 2012)	Decision support systems.
Topic 6:	business, management, organizational, based, research, paper, trends, firm, enterprise, capabilities, process, erpii, cloud, technologies, influential, geographies, survey, concerns, intelligence, factors	(Luftman et al., 2013) (Luftman & Zadeh, 2011) (Luftman et al., 2012) (Choudhary & Vithayathil, 2013) (Coltman et al., 2011)	IT management, firm performance.
Topic 7:	approach, web, information, based, retrieval, knowledge, financial, results, method, methods, proposed, framework, existing, phishing, study, performance, user, research, formation, bank	(Abbasi et al., 2015) (Mookerjee & Mannino, 1997), (Chung et al., 2005), (Abbasi et al., 2012), (Fan et al., 2005)	Web, Predictive Analytics.

Table 5: Topics extracted using LDA

[3] McCallum, Andrew Kachites. "MALLET: A Machine Learning for Language Toolkit." http://mallet.cs.umass.edu. 2002.

From topic modelling, we can see that some of the underlying research themes in BA IS research are Web, predictive analytics, IT management, business intelligence, IS usage, firm performance and decision support.

Conclusion

Business Analytics (BA) has been growing by leaps and bounds, and researchers are continually looking for new techniques, algorithms, frameworks, and technical architectures to address the myriad challenges that confront organizations that are striving to draw actionable insights from data. However, BA is not about technology and algorithms alone. A good understanding of the organizational factors that facilitate efficacious practice of BA is required as well. Research studies to address these concerns have been appearing in premier IS journals for a while now. Our study uses citation and text analyses to enumerate the conceptual structure of BA as reflected in articles published in the IS scholars' basket of eight journals.

In addition to revealing the reference disciplines that have influenced BA research in IS, our study found that Web, predictive analytics, business intelligence, IT management, firm performance and decision support are some of the most important areas BA-related research being pursued by IS scholars. Although tentative, our findings have implications for practitioners and academics alike. First, our study identifies reference disciplines such as economics, sociology and psychology, to name but a few, that practitioners seldom mention when they discuss data science or BA. The influence of these disciplines on BA research within IS suggests that data alone is not enough, but an understanding of human nature and behaviors is essential to derive business value through BA. For academics, this opens several avenues of research, including how one might alter human behavior in desirable ways based on data-driven insights. Second, the themes we unravel through topic modeling and K-Means clustering give a hint of the opportunities that exist in BA, as well as showing the gap between academic research and the practice of BA. For example, nascent areas such as the Internet of Things (IoT) and deep learning, are conspicuously missing from our topics list.

In this work, we did not study the temporal evolution of topics. This may be a fruitful area of future research. Also, given the paucity of research on BA within the IS discipline, we could not conduct any of the statistical tests of significance about the influence of reference disciplines on BA-related IS research. Rather, we relied upon descriptive methods to uncover the hidden topics and themes based on text and citation data. Also, our selection of articles is restricted to IS senior scholar's basket of eight and that too only for articles indexed by the Web of Science citation database. Hence our results although provides some initial view of the intellectual structure of BA in IS are restricted to the main stream IS journals and does not provide a holistic view of the BA field from perspective of other disciplines. While identifying the reference disciplines in citation analyses we eliminated approximately half cited references with elimination of those been cited less than 10 times in given year. Although this practice is consistent with what is used in (Agarwal, 2016) it might have slightly affected our citation analyses results. Currently, we are working on eliminating these restrictions as future enhancements of this research. Although we only investigated how BA articles in IS borrowed ideas/concepts from other disciplines, it may be insightful to understand the nature of concepts being borrowed by others from the BA-IS literature. Despite its limitations, the study makes some valuable contributions and is a first step towards articulating a research agenda geared towards providing a deeper understanding of how BA had evolved and may bring value to a firm.

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