Small Data to Big Data
The Information Systems (IS) Continuum

Ciara Heavin, Mary Daly and Frederic Adam
Business Information Systems, University College Cork, Cork, Ireland

Keywords: Data, Information, Knowledge, Knowledge Management (KM), Big Data, Information Systems (IS) and IS Continuum.

Abstract: Since the beginning of the 20th century and the emergence of modern business, organisations large and small have increasingly struggled to get to grips with the rising tide of their critical data. This led to a period during the 1970s and 1980s where much focus was directed towards managing information as a specific activity, increasingly carried out by experts. The 1990s brought the notion of knowledge management (KM), the knowledge organisation and subsequently the knowledge society. However since the turn of the decade, IS researchers have again turned their attention to the specific issue of dealing with unprecedented volumes of data. This new tidal wave has been referred to as 'Big Data' – large volumes of data amassed for organisations, requiring extensive storage, management, processing and analytic capabilities. Through a review of seminal literature, this paper proposes an Information Systems (IS) continuum defined primarily as a factor of time, phenomenological focus and developments in technology which conceptualises Big Data as a natural extension of the data, information and knowledge continuum. Based on this proposal, the paper considers the implications of this formalisation for IS researchers.

1 INTRODUCTION

Organisations of the past have struggled with issues such as managing large volumes of data and information (Huber, 1982; Huber and Daft, 1987), developing their ability to react to external environmental uncertainty (Daft and Lengel, 1986; Earl and Hopwood, 1980; Huber and McDaniel, 1986 and MacCrimmon, 1985) and coping with constant advances in technology (Huber and McDaniel, 1986; Huseman and Miles, 1988 and Mentzas, 1994). Subsequently, Knowledge Management (KM) researchers (Alavi and Leidner, 2001; Davenport and Prusak, 1998; Galliers and Newell, 2001; Nonaka and Takeuchi, 1995; O'Dell and Grayson, 1998 and Pfeffer and Sutton, 1999) continued to consider many of the same issues, albeit under a new banner. However, the focus on KM as an organisational strategy truly found attention through Drucker's (1992) postulations that *"the basic economic resource – the means of production – is no longer capital, nor natural resources, nor labor. It is and will be knowledge"*. While knowledge remains a core organisational and societal resource, the notion of 'Big Data' and developing and understanding an organisation's ability to extract relevant knowledge and associated insights using sophisticated technology have become priorities for both academia and industry alike.

With this in mind, a discussion of information and knowledge would not be complete without considering the concepts of data and big data. Alavi and Leidner (2001) purport that establishing a distinction between data, information and knowledge is a feature of IT related research. This remains true for big data, not only has the focus on 'Big Data' gained momentum; the attention attributed to 'Big Data' technologies, e.g. Hadoop, MapReduce, Hive, is extraordinary. Organisations increasingly focus their attention on how to process and analyse the significant volumes of data being generated, predominantly across the web, about their products/services/reputations etc. Notably, ten years ago IS and relating literature (in cognate disciplines) were concerned with organisations' ability to 'manage what they know' in order to improve their competitive position. In 2014 firms are consumed with how their ability *"to collect, manage and analyze data effectively can lead to better business decisions and lasting competitive advantage"* (Financial Executive, 2012). Underpinned by our

Heavin C., Daly M. and Adam F..
Small Data to Big Data - The Information Systems (IS) Continuum.
DOI: 10.5220/0005133802890297
In *Proceedings of the International Conference on Knowledge Management and Information Sharing* (KMIS-2014), pages 289-297
ISBN: 978-989-758-050-5

observations of the permanency of this organisational quest, the objective of this paper is to consider the journey from small data to big data along the IS continuum using seminal literature to characterise data, information, knowledge and big data and the technology that underpins each of these stages in the continuum.

This paper is organised as follows, the next section positions data and information in the field of Information Systems (IS) and subsequently the nature of knowledge and KM are presented. The notion of Big Data is then considered and the authors characterise the shape of the IS continuum in terms of these phenomenon. Finally, some predictions are made about the direction of the IS continuum into the future.

2 UNPACKING THE IS CONTINUUM

2.1 Data and Information

While extant research (Alavi and Leidner, 1999; Davenport and Prusak, 1998; Zack, 1999) contests the 'which comes first' argument; i.e. data, information, or knowledge, this study considers each of these concepts in terms of their chronological emergence in IS and related literature. With this, the nature of big data and its place in the IS Continuum is considered.

Data is *"a set of discrete, objective facts about events"* (Davenport and Prusak, 1998). Thus, data is assumed to be isolated facts. It can be in the form of numbers, text, images and sound, and is essentially the raw material of management in any organisation (Duffy, 1999). According to Davenport and Prusak (1998) from an organisational perspective data may be described as *"structured records of transactions"*. Whilst some agreement exists in the literature with respect to defining data, Mintzberg (1975) endeavoured to take this one step further and differentiate between different types of data. He defined hard data as figures, documents, formula, by contrast to soft data which encompass judgements and opinions. On the other hand, soft data may be widely known and accepted (explicit e.g. someone's opinion or view) but may not be officially codified (Mintzberg, 1975). This heightened level of complexity set the seed for a debate that was due to occur approximately twenty years later in terms of defining knowledge.

Information is generally considered to differ from data as it holds meaning for specific actors (Spender, 2004). Information *is "a message, usually in the form of a document or an audible or visible communication"* (Duffy, 1999). Information is created when isolated facts are put into context, and combined within a structure (Davenport and Prusak, 1998). According to Bennet and Bennet (2004) *"Information is data with some level of meaning. It is usually presented to describe a situation or a condition and therefore has added value over data"*. In addition, Daft and Macintosh (1981) postulate that in order *"to qualify as information, the data must effect a change in the individual's understanding of reality"*. This presents a sophisticated view of information, moving away from the 'information as an object' school of thought to consider the effect of information on the individual. In 1991, Huber acknowledged that organisations in general cope with hard information regularly but the soft or non-routine information mentally stored by people (Mintzberg, 1975) is not well considered. Mintzberg (1975) identified that managers routinely acquire and mentally store soft information. Huber (1991) also used the term *"soft information"* to deal with that information local to experts which is utilised to deal with specific tasks such as diagnosing equipment malfunctions, identifying subject matter external to the organisations and uncovering information using unofficial mechanisms. According to Mintzberg (1975) verbal information is stored in people's minds and it is only when this information is written down that it can be stored in tangible files in the organisation. By its very nature, this type of information is more difficult to capture, codify and store. Table 1 provides an overview of common definitions for data and information.

Table 1: Overview of data and information.

Data	Information
Structured records of transactions (Davenport and Prusak, 1998) Soft data – judgements and opinions (widely known and accepted) (Mintzberg, 1975) Hard data – figures, documents and formula (Mintzberg, 1975; Duffy, 1999; Bennet and Bennet, 2004)	Structured data used in a specific context e.g. message, document (Davenport and Prusak, 1998; Duffy, 1999; Zack, 1999) Data with meaning (Bennet and Bennet, 2004; Spender, 2004) Soft information (Huber, 1991) or verbal information (Mintzberg, 1990) – information local to experts Expert Information – information codified and captured in an information system (Huber, 1991)

Table 1 illustrates that while data and information display independent characteristics they are interrelated and not dichotomous; data is an intrinsic component of information. However, Zuboff (1991) highlighted the difficulties associated with the notion of *"informating an organisation"* as *"processes, objects, behaviours, and events are translated into and made visible as explicit information"* (Zuboff, 1991, p5). In order to informate, all relevant information is codified, rationalized, explicated and made public (Zuboff, 1991). From an organisational perspective, Ackoff (1967) contends that attention is primarily given to the generation, storage and retrieval of information but in order to overcome the abundance of useless information, filtration (evaluation) and condensation should be an organisational priority. As information became increasingly characterised by complex processing and value generation, so did the concept of knowledge become more prevalent in IS literature. The conversion of data into information requires specialised knowledge, which evolves through the synchrony of many specialists and specialties in the organisation (Drucker, 1988), and that knowledge may be a company's greatest competitive advantage (Davenport and Prusak, 1998) as knowledge is considered the only *"meaningful economic resource"* (Drucker, 1992). The following section considers the emergence of the concept of knowledge in IS literature focusing on the relationship between data, information and knowledge, the relationship between information and knowledge being perceived as the most important.

2.2 The Nature of Knowledge

The focus on knowledge as an organisational resource came long before the notion of KM: as economies shifted into the information age, information and knowledge became the most vital organisational resources (Bell, 1979). However, justifying the distinction between data, information and knowledge is a difficult and contentious endeavour. The more commonly held belief is that data sits at the bottom of the hierarchy; information is derived from data and knowledge is information validated through experience, judgement or context (Davenport and Prusak, 1998). Figure 1 distinguishes between the levels of data, information and knowledge.

The nature of information is such that it can easily be externalised and is therefore easily shared, while knowledge is mostly internalised and personal to an individual. Alavi and Leidner, (2001) challenge this conceptualisation, highlighting the difficulty in distinguishing information and knowledge. Previous research has argued that

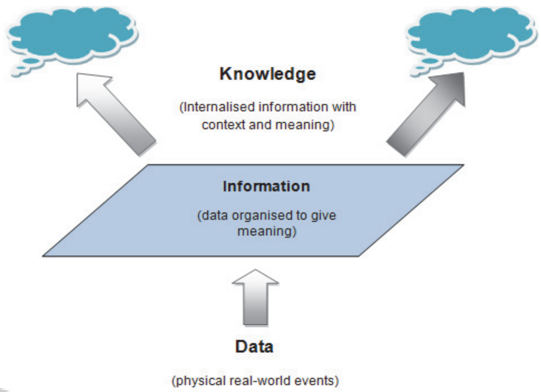

Figure 1: Data, information and knowledge (Meredith *et al.*, 2000).

research has argued that knowledge may be viewed in many ways; as 'know-how' by Huber (1981), a state of mind (Alavi and Leidner, 2001; Polanyi, 1966; Spender, 2004), an object (Stein and Zwass, 1995;), a process (Zyngier, 2002), a condition of accessing information (Bennet and Bennet, 2004; Davenport and Prusak, 1998; O'Dell and Grayson, 1998). Churchman (1971) describes knowledge from three different perspectives; knowledge as a collection; knowledge as an activity; knowledge as a potential. His conceptualisation of knowledge as an activity and as a potential implies that the value of knowledge increases when someone knows how to do something correctly, as well as their ability (knowledge) to learn as their circumstances change (Courtney, 2001). Churchman's (1971) conceptualisation of knowledge as a collection and his statement that *"knowledge resides in the user and not in the collection of information… it is how the user reacts to a collection of information that matters"* points to the personalised nature of

Table 2: Knowledge definitions.

Knowledge Definition	Author
"Knowledge is information possessed in the minds of individuals: it is personalized information (which may or may not be unique, useful, or accurate) related facts, procedures, concepts, interpretations, ideas, observations, and judgements".	Alavi and Leidner (2001)
"Knowledge is built on data and information and is created within the individual. Knowledge, of course, has many levels and is usually related to a given domain of interest." "Knowledge represents understanding of the context, insights into relationships within a system, and the ability to identify leverage points and weaknesses and to understand future implications of actions taken to resolve problems"	Bennet and Bennet (2004, pp8)
"Knowledge is a fluid mix of framed experiences, values, contextual information, and expert insights that provide a framework for evaluating and incorporating new experiences and information".	Davenport and Prusak (1998)
"Complex products of learning, such as interpretations of information, beliefs about cause –effect relationships, or, more generally, know-how".	Huber (1991, pp89)
"Knowledge is a function of a particular stance or perspective….., unlike information it is about action"	Nonaka and Takeuchi (1995, pp58)
"Knowledge is what people in an organisation know about their customer, products, processes, mistakes, and successes and whether that knowledge is explicit or tacit".	O'Dell and Grayson (1998, pp5)
"justified true belief"	Plato (Cooper J.M. and Hutchinson D.S. (eds), 1997)
"Knowledge has meaning when it can be readily associated with the contextualized actions of our experience"	Spender (2004, pp60)
"Knowledge is not factual information but it is the product of human intercourse, a process as applied to a given context".	Zyngier (2002)

knowledge. In the organisational environment of the twenty first century, when information is abundant and always available, it is interesting to realise that *"only that information which is actively processed in the mind of an individual through a process of reflection, enlightenment and learning, can be useful"* (Alavi and Leidner, 1999). Table 2 includes some of the most widely cited knowledge definitions.

Table 2 yields a picture of knowledge where personalised interpretation and understanding are critical. In the Data Processing era, the notions of hard and soft data had been introduced. In the Information Management era, the concepts of hard/routine and soft/non-routine information were proposed. In the knowledge management (KM) era the discussion continued with the proposed distinction between explicit and tacit knowledge. Crucially, tacit and explicit knowledge should not be considered as a dichotomy but as complementary elements of knowledge that are critical to the organisation. Moving away from the hierarchical view of data, information and knowledge embodied in the move from data processing to information management, the next section endeavours to present the concept of KM and its emergence in IS literature.

3 1990S AND THE ARRIVAL OF KNOWLEDGE MANAGEMENT (KM)

An organisation's ability to manage knowledge is deemed essential in terms of its development as a strategic asset (Kakabadse *et al*., 2001). The following section presents the range of views in terms of how KM should be described in an organisational context. According to Kirrane (1999) the generation of information into valuable organisational knowledge integrates organisational learning, performance management and quality management leading to enhanced decision making and action. Wiig (1993) states that improvements in KM have resulted in *"factors that lead to superior performance: organisational creativity, operational effectiveness and quality of product and services"*. Alavi and Leidner (2001) characterise KM as a process involving activities: creating, storing/retrieving, transferring and applying knowledge.

While the concept of KM is not new, the focus on KM as a strategy has increased in the last twenty years as organisations realise the importance of knowledge as an intangible asset contributing to the enhancement of competitive advantage (Bolloju and Khalifa, 2000). In an economic environment where organisations have been forced to take a step back and re-evaluate their core competencies and ability to innovate, organisational knowledge has come to the forefront as a valuable strategic asset (Haghirian, 2003).

Managing knowledge remains on the agenda as organisations endeavour to *"know what they know"* (O'Dell and Grayson, 1998; Davenport and Prusak, 1998) and use this resource to their advantage to increase organisational competitiveness (Davenport and Prusak, 1998; O'Dell and Grayson, 1998) and to avoid reinventing the wheel (McDermott and O'Dell, 2001). While research acknowledges the importance of KM, it is the complexity of knowledge coupled with the 'new' dimensions such as technology (i.e. knowledge management systems (KMS), document management systems, intranet, wiki technology and blogs) which compound the difficulties associated with managing knowledge in order to store and use it in the future. These new dimensions have been acerbated with the growing emphasis on the opportunities associated with big data (Kabir and Carayannis, 2013). Indeed, big data and its lauded advantages is completely underpinned by sophisticated and complex technologies (Kabir and Carayannis, 2013). The following section outlines big data within the context of the data, information and knowledge evolution, the most recent addition to the IS literature.

4 BIG DATA, BETTER INSIGHTS

Big Data describes a dataset that is so large and complex that it *"require(s) advanced and unique data storage, management, analysis and visualisation technologies"* (Chen *et al*., 2012). An enormous amount of industry, company, product and customer data can be gathered from many external and internet sources including online social media forums, web blogs and social networking sites, most of which is unstructured and is considered to be 'Big data'. Big data refers to such a vast amount of data that conventional data warehouse technologies could not store, manage or analyse it, but which is required by organisations *"to provide greater insights when assessing new business opportunities and for better decision making"* (Rahman, Aldhaban and Akhter, 2013). The three key attributes of big data are volume, velocity and variety. These attributes capture the essence of big data:

- the large volumes of data that are available and the benefits from having more data
- despite the large volume of data, data can be processed faster
- data is messy and complex due to the many sources of the data and the many formats of the data with more than ninety per cent of big data being unstructured (McAfee and Brynjolfsson, 2012) and inconsistent (Lycett, 2013).

Some researchers include '*value'* as a fourth "V", indicating that Big Data and Business Analytics (BA) are key differentiators (LaValle, Lesser, Shockley, Hopkins and Kruschwitz, 2011; Davenport, 2013) to guide both future strategies and day-to-day operations (Lycett, 2013). Each of these attributes (volume, velocity variety and value) in turn, gives rise to a new technological challenge to cater for associated specific demands. For example, collecting large amounts of big data requires new technologies for storage and more powerful levels of computing power to do the data crunching and analysis.

Since data is the underlying resource for Business Intelligence (BI), a central component of BI systems is the Data Warehouse, which integrates data from various transactional IS for analytical purposes, and which involves the structuring, storage and use of large amounts of high quality data. Many empirical reports on the impacts of BI, BA and Big data have been inconclusive, especially where managers are operating within highly uncertain situations (Speier and Morris, 2003; Speier, 2006; Buhl, Röglinger, Moser and Heidemann, 2013; Lycett, 2013). The Data Analytics area and the corresponding Big Data discussion are mostly predicated on the idea that managers need presentational and computational help in dealing with the volume of data available to them. Many of the recent initiatives in the BI, BA and Big Data domains are vendor-led and despite the claims of software vendors there is some evidence that the problems inherent in proposing effective decision support are of such a nature that technology solutions alone are unlikely to solve the real decision problems conclusively and Lycett (2013, p. 381) contends that the primary barrier to achieving the promise of big data is the *"lack of understanding of how to use analytics to improve the business*". Moreover BI systems can make it even harder to support the manager's awareness and focus of weak signals in the environment, many of which may be effectively filtered out by structured BI tools (Ilmola and Kuusi, 2006; Hiltunen, 2008). Interestingly, Huber (1981) suggested that IS are almost all designed to function in a rational decision making environment, even though decision environments vary greatly across different organisations.

The following section considers the range of phenomena characterised as part of this paper which is illustrated as a continuum.

5 ESTABLISHING THE IS CONTINUUM

The concept of a continuum in IS is widely considered (Davis and Wetherbe, 1979; Mason and Mitroff, 1973; Davenport and Prusak, 1998; Wurman, 2001). For the purpose of this study a continuum is defined as a *"continuous sequence in which adjacent elements are not perceptibly different from each other, but the extremes are quite distinct."* (Oxford English Dictionary, 2005). Indeed Kettinger and Li (2010) purport that *"clearly defined relationships between core concepts in our field are the bedrock for building a cumulative tradition"*. Subsequently, the objective of this paper is motivated by this assertion. That being said, defining and characterising the nature of data, information, knowledge and more recently big data as distinct and independent phenomena is an arduous endeavour. In particular it is noted that many authors use the terms information and knowledge interchangeably, those (Dennis, Earl, El Sawy, Huber) that considered organisational information processing in the 1970s, 1980s and early 1990s refocused their attentions on KM as an organisational strategy. Considering the nature of big data, Provost and Fawcett (2013) suggest that there is little value in defining the boundary of big data and data science, they expend their efforts by exploring the fundamentals and principles underpinning big data and in doing so consider the nature of organisational information and knowledge. Figure 2 represents data, information, knowledge and big data and the associated technologies as a continuum.

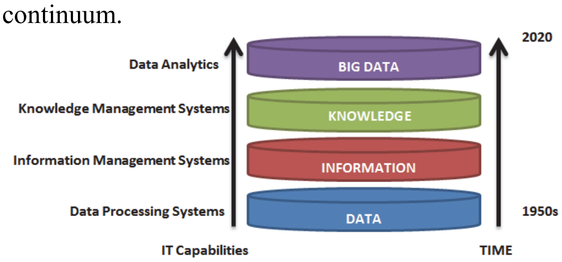

Figure 2: IS continuum.

Reflecting on the dictionary definition of 'continuum' outlined, it is evident that the extremes of each phenomenon are distinct however there is significant overlap between data/information and information/knowledge. According to Davenport and Prusak (1998) *"the distinction between knowledge and information is seen as more of a continuum than a sharp dichotomy. Most projects that focus on internal knowledge [repository] deal with the middle of the continuum- information that represents knowledge to certain users"*. Alavi and Leidner (2001, p109) posit that "*information is converted to knowledge once it is processed in the minds of individuals*" while *"knowledge becomes information once it is articulated and presented in the form of text, graphics, words or other symbolic forms"*. The point where information becomes knowledge and vice versa is difficult to pinpoint with complete accuracy, however there is no doubt that these phenomena are closely linked. In the case of Davenport and Prusak's (1998) knowledge repository, information captured in a store represents knowledge to a group focused on a particular task e.g. a project. While it may be argued that this is information, it is how this information is used that reflects the characteristics of knowledge – *"information in action"* (O'Dell and Grayson, 1998). Considering the nature of big data, it is important to acknowledge the volume and variety of big data as key differentiating characteristics, however beyond this, like the other phenomenon, the boundary is somewhat blurred. Big data acts as a source of knowledge, while associations between the data items may provide information about other data (Provost and Fawcett, 2013). Knowledge visualisation techniques are utilised to illustrate these associations to help improve the transfer and creation of knowledge between at least two parties (Eppler, 2004). LaValle et al. (2012) acknowledge that senior managers require ways to *"make information come alive",* and this may be achieved through types of visualization and process simulation techniques. It is the extraction of hidden information from large volumes of data that enables firms to make proactive, knowledge-driven decisions (O'Flaherty and Heavin, 2014).

It is not uncommon to come across such continuums in research, Starbuck (1976) pointed out that, the boundaries of organisations themselves are permeable such that: assuming that organisations can be sharply identified from their environments distorts reality by compressing into one dichotomy a combination of continuously varying phenomena (p1069). Similarly, the boundaries between data, information, knowledge and Big Data are indeterminable and as a result these four concepts can properly be presented as a continuum of interrelated phenomena.

6 CONCLUSIONS

This paper presents the concept of data, information, knowledge and big data along the IS continuum as a factor of time (since the 1950s) underpinned by the technological evolution of computing tools to store, process, analyse and visualise data. Without underestimating the nature and level of complexity associated with technology, at the core of the continuum remain organisations who continue to experience problems, to identify opportunities and who are striving to make better decisions.

Notwithstanding the considerations presented in this paper, some thought should be given to the ensuing possibilities for the IS continuum. Some suggest that the development of 'Big Knowledge Management' strategies are required in order for organisations to develop capabilities which allow them to identify what they need to extract from the big data, the types of knowledge visualisations required to support the needs of decision makers and also to better understand what they do not know (Financial Executives, 2012). Others contend that organisations must revisit their KM strategies to consider and incorporate 'Big Data' (Kabir and Carayannis, 2013; TCS, 2013). Notably, some commentary indicates that organisations need to effectively leverage their existing data, information and knowledge as a means of improving their decision making capabilities before they make significant investments in big data and big data technology (Ross et al., 2013). In support, Ross et al. (2013) contend that *"very few companies know how to exploit the data already embedded in their core operating systems"*.

In his characterisation of the post-industrial organisation, Huber (1984) was ahead of his time. He envisaged a 'self-designing' organisation focused on the acquisition of soft information for decision making and innovation (Huber, 1984). Essentially, Huber (1984) prescribed that firms need to structure themselves for making decision and for action, not for processing information. With this in mind, from a practitioner perspective it is imperative that managers develop a more sophisticated appreciation for data / information / knowledge / big data. By doing this, they may be able to establish processes that enable them to be flexible enough, using the appropriate technology, to leverage these resources in the right way, at the right time to react to environmental uncertainty.

As IS researchers, by carving out the IS continuum we avoid perpetuating the ‘which came first’ debate and subsequently avoid ‘reinventing the wheel’. This means that greater attention may be paid to supporting organisations in addressing their needs enabling them to leverage sophisticated technologies to achieve their objectives.

REFERENCES

Ackoff, R. L. (1967). "Management Misinformation Systems." Management Science 14(4): 147-156.

Alavi, M. and D. E. Leidner (1999). "Knowledge management systems: issues, challenges, and benefits." Communications of the AIS 1(2es): 1.

Alavi, M. and D. E. Leidner (2001). "Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues." MIS quarterly: 107-136.

Bell, D. (1979) “The Social Framework of the Information Society”, in M.L. Dertoozos and J. Moses, (eds.), *The Computer Age: A 20 Year View*, Cambridge, MA: MIT Press, 1979: 500-549.

Bennet, A. and Bennet, D. (2004) “The Rise of the Knowledge Organization”, *The Handbook on Knowledge Management Volume 1,* (Eds). C.W. Holsapple, Springer, Germany: 1-20.

Bolloju, N. and Khalifa, M. (2000) “A Framework for Integrating Decision Support and Knowledge Management in Enterprise-wide Decision making Environments”, IFIP TC8/WG8.3 International Conference on Decision Support through Knowledge Management, 9-11 July 2000, Stockholm, Sweden: 60-76.

Buhl, H. U., M. Röglinger, D.-K. F. Moser and J. Heidemann (2013). "Big Data." Wirtschaftsinformatik 55(2): 63-68.

Chen, H., R. H. Chiang and V. C. Storey (2012). "Business Intelligence and Analytics: From Big Data to Big Impact." MIS Quarterly 36(4).

Churchman, C. W. (1971). The design of inquiring systems: basic concepts of systems and organisation. New York, Palgrave Macmillan Ltd.

Cooper J.M. and Hutchinson D.S. (eds) (1997) Plato: Complete Work, Hackett Publishing Company: Indianapolis, pp. 557-595.

Courtney, J. F. (2001). "Decision making and knowledge management in inquiring organizations: toward a new decision-making paradigm for DSS." Decision Support Systems 31(1): 17-38.

Daft, R. and R. Lengel (1986). "Organizational Information Requirements, Media Richness and Structural Design." Management Science 32(5): 554-571.

Daft, R. L. and N. B. Macintosh (1981). "A tentative exploration into the amount and equivocality of information processing in organizational work units." Administrative Science Quarterly: 207-224.

Daft, R. L. and K. E. Weick (1984). "Toward a Model of Organizations as Interpretation Systems." Academy of Management Review 9(2): 284-295.

Davenport, T. H. (2013). "Keep Up with Your Quants." Harvard Business Review 91(7-8).

Davenport, T. H. and L. Prusak (1998). "Working knowledge: Managing what your organization knows." Harvard Business School Press, Boston, MA.

Davis, C. K. and Wetherbe, J.C. (1979) “An Analysis of the Impact of Distributed Data Processing on Organizations in the 1980s”, *MIS Quarterly*, 3(4). 47-56.

Drucker, P. (1988). "The coming of the new organization." Harvard Business Review 66(1): 45-53.

Drucker, P. (1992). Managing for the future. Oxford, Butterworth Heinemann.

Drucker, P. (1995). "Long-Range Planning: Challenge to Management Science." Management Science 5(3): 238-249.

Duffy, N.M. (1999) “Benchmarking Knowledge Strategy”, In N.Duffy, A. Jooste & L. Whittaker (Eds.), *Leveraging Knowledge for Business Performance,* Wits Business School, Johannesburg: 12-24.

Earl, M. J. and A. G. Hopwood, Eds. (1980). From management information to information management. The Information Systems Environment. North-Holland.

Eppler, M.J. (2004) Facilitating Knowledge Communication through Joint Interactive Visualization, Journal of Universal Computer Science, 10(6): 683-690.

Financial Executive, (2012) “Big Data + Big Analytics = Big Opportunity” http://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/big-data-big-opportunity.pdf [last accessed 20/6/14]

Galliers, R.D. and Newell, S. (2001) “Back to the Future: From Knowledge Management to Data Management”, In *Global Co-Operation in the New Millennium, The 9th European Conference on Information Systems*, Bled, Slovenia, June 27-29: 609-615.

Haghirian**,** P. (2003) “Does Culture Really Matter? Cultural Influences on the Knowledge Transfer Process within Multinational Corporations”, *Proceedings of the 11th European Conference on Information Systems*: 740-751.

Hiltunen, E. (2008). "The future sign and its three dimensions." Futures 40(3): 247-260.

Holsapple, C. and Joshi, K. (2004) “A Knowledge Management Ontology”, *Handbook on Knowledge Management Volume 1*, (Eds) Holsapple, C.W., Verlanger: Berlin: 89-128.

Huber, G. (1981). "The Nature of Organizational Decision Making and the Design of Decision Support Systems." MIS Quarterly 5(2): 1-10.

Huber, G. (1982). "Organizational information systems: Determinants of their performance and behavior."

Management Science: 138-155.
Huber, G.P. (1984) "The Nature and Design of Post Industrial Organisations", *Management Science*, 30(8): 928-951.
Huber, G. P. and R. L. Daft (1987). "The information environments of organizations."
Huber, G. P. and R. R. McDaniel (1986). "The Decision-Making Paradigm of Organizational Design." Management Science 32(5): 572-589.
Huseman, R. C. and Miles, E. W. (1988) "Organisational Communication in the Information Age: Implications of Computer-Based Systems", *Journal of Management*, 14(2): 181-204.
Ilmola, L. and O. Kuusi (2006). "Filters of weak signals hinder foresight: Monitoring weak signals efficiently in corporate decision-making." Futures 38(8): 908-924.
Kabir, N., & Carayannis, E. (2013). Big Data, Tacit Knowledge and Organizational Competitiveness. *Journal of Intelligence Studies in Business*, *3*(3).
Kakabadse, N. K., Kouzmin, A. and Kakabadse, A. (2001) *"From tacit knowledge to knowledge management: leveraging invisible assets"*, Knowledge and Process Management, 8(3): 137-154.
Kettinger, William J., and Yuan Li. "The infological equation extended: towards conceptual clarity in the relationship between data, information and knowledge." *European Journal of Information Systems* 19.4 (2010): 409-421.
Kirrane, D.E. (1999) "Getting wise to Knowledge Management", *Association Management*, 51(8): 31-42.
LaValle, S., E. Lesser, R. Shockley, M. S. Hopkins and N. Kruschwitz (2011). "Big data, analytics and the path from insights to value." MIT Sloan Management Review 52(2): 21-32.
Lycett, M. (2013). "'Datafication': making sense of (big) data in a complex world." European Journal of Information Systems 22(4): 381-386.
MacCrimmon, K.R. (1985) "Understanding strategic decisions: three systematic approaches", in Pennings *et al.* (Eds), *Organisational Strategy and Change*, Jossey-Bass Publishers, London.
Mason, R.O. and Mitroff, I.I. (1973) "A program for research on management information systems", *Management Science*, 19: 475-485.
McAfee, A. and E. Brynjolfsson (2012). "Big data: the management revolution." Harvard business review 90(10): 60-68.
McDermott, R. and O'Dell, C. (2001) "Overcoming Cultural Barriers to Sharing Knowledge", *Journal of Knowledge Management*, 5(1): 76-85.
Mentzas, G. (1994). "A functional taxonomy of computer-based information systems." International journal of information management 14(6): 397-410.
Meredith, R. May, D. and Piorun, J. (2000) "Looking at Knowledge in Three Dimensions", IFIP TC8/WG8.3 *International Conference on Decision Support through Knowledge Management*, 9-11 July 2000, Stockholm, Sweden: 241-254.
Mintzberg, H. (1975) "The Manager's Job: Folklore and Fact", *Harvard Business Review*, Jul./Aug.: 49-61.
Nonaka, I. and Takeuchi, H. (1995) *The Knowledge-Creating Company*. Oxford University Press, New York, NY.
O'Dell, C., Grayson, C.J.J. (1998) If Only We Knew What We Know: The Transfer of Internal Knowledge and Best Practice, The Free Press, New York, NY.
O'Flaherty, B. and Heavin, C.(2014), "Positioning Predictive Analytics – A Design Evaluation", DSS 2.0 – Supporting decision making with new technologies IFIP WG 8.3 June 2014, Paris, France.
Oxford English Dictionary of Current English (Compact) (2005), Third Edition ISBN-13: 978-0-19-861022-9.
Pfeffer, J. and R. I. Sutton (2006). Evidence-Based Management. Harvard Business Review 84(1): 62-74.
Polanyi, M. (1966) The *Tacit Dimension*. Routledge and Kegan Paul, London, UK.
Porter, M. and V. Millar (1985). How information changes the way you compete. Harvard Business Review: 149-160.
Provost, F., and Fawcett, T. 2013. "Data Science and Its
Relationship to Big Data and Data-Driven Decision Making." Big Data 1(1):51–59.
Rahman, N., F. Aldhaban and S. Akhter (2013). Emerging technologies in business intelligence. Technology Management in the IT-Driven Services (PICMET), 2013 Proceedings of PICMET'13:, IEEE.
Ross, Jeanna W., Cynthia M. Beath, and Anne Quaadgras. 2013. You May Not Need Big Data After All. December. http://hbr.org/2013/12/you-may-not-need-big-data-after-all/ar/1.[last accessed 20/6/14]
Spender, J.C. (2004) "Knowledge Fields: Some Post -9/11 Thoughts about the Knowledge Based Theory of the Firm", *The Handbook of Knowledge Management Volume 1*, Eds. C.W. Holsapple, Verlanger: Berlin: 59-72.
Speier, C. (2006). "The influence of information presentation formats on complex task decision-making performance." International Journal of Human-Computer Studies 64(11): 1115-1131.
Speier, C. and M. G. Morris (2003). "The influence of query interface design on decision-making performance." MIS Quarterly 27(3): 397-423.
Starbuck, W. H. (1976) "Organisations and their environments", in Dunnette (Ed.) *Handbook of Industrial and Organisational Psychology*, Rand McNally College Publishing Company, Chicago: 1069-1123.
Stein, E.W. and Zwass, V. (1995) "Actualizing organizational memory with information systems", *Information Systems Research*, 6(2): 85-118.
Tata Consulting Services (TCS) (2013) "Managing Knowledge from Big Data Analytics in Product Development"http://www.tcs.com/SiteCollectionDocuments/White%20Papers/Knowledge-Big-Data-Analytics-Product-Development-1213-1.pdf [last accessed 20/6/14]
Wiig, K.M. (1993) *Knowledge Management Foundations – Thinking About Thinking – How People and*

Organizations Create, Represent, and Use Knowledge. Schema Press, Arlington, TX.
Wurman, R. S. (2001) *Information Anxiety 2*. Que, Indiana, USA.
Zack, M.H. (1999) “Managing codified Knowledge”, *Sloan Management Review*, 40(4): 45-58.
Zyngier, S. (2002) “Knowledge Management Obstacles in Australia”, *European Conference on Information Systems*, Poland: 919-928.
Zuboff, S. (1991) “Informate the Enterprise: An Agenda for the Twenty-First Century”, *National Forum: The Phi Kappa Phi Journal*, Vol. LXXI, No. 3