Future Applications of Blockchain in Business and Management: a Delphi study

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Main Message:
Blockchain has the potential to become a significant source of disruptive innovations in business and management.

Key Points:
There is a scarcity of knowledge and understanding of blockchain techniques that hinders its academic research and practical application.

Business managers need to understand the potential impact and threat of blockchain applications in order to gain and maintain competitive advantage.

Business and management blockchain applications appear to offer considerable performance improvement and commercialisation opportunities.

JEL Codes: C83, M00, M15, O33

Article Running Head: Blockchain Applications

1. Introduction

The appearance of new technologies has often heralded radical transformations of the ways of doing work and disruptive social change has been concomitant. Steam, for example, powered the industrialization of economies and fostered the displacement of large segments of the working populace as well as laying the foundations for seemingly unstoppable environmental decline (Lewandowsky, 2016; Kittel, 1967) while the internet revolution has arguably been the most significant since the industrial and its effects upon business and society cannot be underestimated nor reliably further predicted (Agarwal, 2015; Feldman, 2002). Some technologies are, or have been, forecast to have the potential to generate further radical transformation of ways of working and ways of living. 3D Printing and Augmented Reality for example have been the subject of much debate, but the actuality has so far failed to live up to expectations (Mishra, 2013; Thierer, 2013).

Blockchain promises similarly startling disruption to business and society (Naughton, 2016). One must be careful however not to conflate 'radical', 'innovative' or similar synonymical verbiage with 'revolutionary' during the early stages of technology implementation and adoption: the rollercoaster emergence of Bitcoin for instance has been well documented (Chuen, 2016; Khan, 2015; Higgins, 2015; Simonite, 2015; Edwards, 2015; Dyson, 2014; Feld, Schonfeld and Werner, 2014). The potential impact of blockchain however, both positive and negative, cannot be ignored and it has become the subject of numerous articles in technical and practitioner magazines (for example, Baxendale, 2016 and Rutkin, 2016).

Despite the emergence of Bitcoin in 2008, literature about the application and influence of the underlying blockchain techniques only began to appear from around 2013. In responding to the special issue's call, and to address the paucity of literature on the subject, this study is guided by the broad question *"how blockchain may be expected to change the future of* *business?*". It seeks to provide insight by eliciting the insight of an expert panel through the use of a Delphi study, guided by the prognostications within the limited extant literature.

This paper first provides an overview of the concept of blockchain before it is conceptualised as a form of disruptive innovation. A structured review of the literature is then conducted in order to identify the key themes and topics of academic and expert discussion. Drawing upon the espoused future applications of blockchain technologies the approach for conducting the Delphi study is then detailed before the findings of the data analyses are presented. The paper concludes by identifying those areas of business where blockchain techniques may have a significant effect and where expert practitioners may consider developing products and services. Suggestions for future research and the development of blockchain knowledge are provided.

1.1 Blockchain: An Overview

A blockchain is a form of digital ledger consisting of 'blocks' of information. Each 'block' contains a record of the transactions that occur within a network. In the case of cryptocurrencies, those transactions are typically movements of currency in exchange for goods or services. Once a predetermined number of transactions are recorded, that 'block' of information is added to the ledger, thus forming a 'chain of blocks', hence the term *blockchain*.

An important element of the technique that maintains the strength of the blockchain is 'hashing'. Each newly added block is encoded with a 'hash'. This is an arithmetically produced code that is generated from the data contained within the block: hashing is a well-known method that is used, for example, to secure passwords. Furthermore, the hash of the new block contains the hash of the previous block. This makes it extremely difficult to falsify new or existing parts of the blockchain since the hash of a previous block determines, in part, the hash of future blocks. In order to change one block the entire blockchain would need to be rewritten.

Generating a single hash is relatively easy but the computational requirements for creating a blockchain rises as their usage grows and the number of transactions that are handled increases. The task is undertaken by 'miners' who are individuals or collectives that dedicate their computing power to generate hashes and thereby facilitate the construction of the blockchain. In return for this the miners are rewarded: for example, Bitcoin miners gain Bitcoins for every successful hash they generate. Rewarding miners introduces competition into the activity and some collectives operate vast computer networks that are dedicated to the task. In addition, by operating an 'open' system whereby hashes are generated and confirmed by independent miners, the blockchain is imbued with a degree of trustworthiness. No single person or entity controls the blockchain 'ledger' and therefore the opportunity to falsify the blockchain or fraudulently add blocks is eliminated. A robust and trustworthy system of validating digital transactions is vital when, for instance, cryptocurrencies are being transferred: the openly validated system of blockchaining eliminates the opportunity for increasing or otherwise falsifying the amount of currency that one holds or the transactions that one has engaged in. This gives the blockchain a novel characteristic compared to tangible ledgers in that it is openly available and visible to anyone. It is the openness and robustness of blockchain that has inspired predictions about how it may be used to revolutionise business and social systems that have previously relied upon trust. For further details and discussions of blockchain principles see for example Bradbury (2013, 2014, 2015) and Kahn (2015).

1.2 Conceptualizing 'Blockchain'

Devised by Christensen (1997), and building upon Schumpeter's (1942) theory of 'creative destruction', Disruptive Innovation (DI) refers to the change that a technology brings to an existing business model. DI is said to occur when new technology makes existing systems obsolete by offering considerable improvements in price, simplification or convenience

(Christensen, 2014) and there are several ways in which DIs can manifest (Markides, 2006). Danneels (2004: 249) defines DI as "*technology that changes the bases of competition by changing the performance metrics along which firms compete*", some DIs however, may initially perform below the level of existing technologies (Adner, 2002). This reflects the cautionary words presented in the introduction to this paper that one must be mindful of the temporal dimension of DI: it may be capable of radical change but it is not necessarily a driver of instantaneous change.

Despite the widespread use of the term within academia and industry (Yu and Hang, 2010; Tellis, 2006), a singular definition of DI is difficult to identify (Assink, 2013) and the concept has received much critical debate (Sandstrom, Berglund and Magnusson, 2014). Schmidt and Druehl (2008) for example, challenge Christensen's (2004) prior assertion that all DI results in improved organisational sustainability and even contest that not all disruptive innovations are in fact disruptive. In light of these arguments Yu and Hang (2010) reviewed the DI literature and identified several ambiguities and misinterpretations, noting not only how future research should progress, but also the managerial implications of its inhibitors and enablers.

Information technologies (IT) have long been recognised as seeds of DI. Examples such as cloud computing (Catinean and Candea, 2013) and RFID (Zhou and Piramuthu, 2012) have been cited. The impact of IT as a DI has proliferated to the extent that IT-specific models of DI have emerged (Carlo, Gaskin, Lyytinen and Rose, 2014; Lyytinnen and Rose, 2003). Lyytinen and Rose's (2003) seminal model classifies three different ways in which IT innovations may be disruptive: through developments in the base technology, in the systems development processes, and in the services that may subsequently be provided. The revised model (Carlo, Gaskin, Lyttinen and Rose, 2014) identifies the significance of the timeliness of implementation and the complexity of issues that surround early and late adoption of disruptive IT. Early adopters may gain some advantage by being able to offer innovative solutions to the marketplace, whereas later adopters may still reap the reward of improved process development but without the added risk of managing immature technologies.

If the claims about blockchain's potential to revolutionise business and society (Naughton, 2016) are true, then it may well meet Lyytinen and Rose's (2003) criteria for being conceptualized as a DI. The method of constructing the blockchain conforms to a development in base technology, the characteristics of the 'open' digital ledger present opportunities for the radical development of business processes, and the whole system facilitates the provision of new services.

2. Structured Literature Review

A structured literature review was performed in February 2016 using selected academic databases in the fields of computing and business management. The 'ACM Digital Library' and 'IEEE Xplore' were used in order to capture computing-related literature, while 'Business Source Complete', 'Emerald' and 'Science Direct' were used for business and social science-related literature: other databases in the respective fields returned no further unique publications. Searches were conducted using the phrases '*blockchain*' and '*block chain'* within the title and abstract of articles in each repository. Duplicate articles within the management databases have been eliminated. There were no duplicate publications within the computing databases. There were no duplications across the business and computing databases.

Tables 1 and 2 show the results of the searches that returned a total of 28 articles. These are reasonably evenly dispersed across the computing (16) and business disciplines (12), however, scholarly articles in the business discipline are noticeably scarce. Even though the technology is considered 'new' it has been existed for almost a decade and, given the stated potential impact of blockchain technologies, this is a rather low figure, equating to less than one publication per month between 2013 and 2015. It remains to be seen whether publication rates increase during 2016 and beyond. The lack of literature on this subject is however not entirely surprising as Maxwell, Speed and Campbell (2015, p208) recently stated, "*there is only a small, technically savvy section of society who understand its principles*".

Table 1, Publications by Repository

	Science Direct	Emerald	Business Source Complete	ACM Digital Library	IEEE Xplore	
2016	1					
2015	2	1	2	4	8	
2014	2	1		1	1	
2013	3				2	
Totals	8	2	2	5	11	28

Table 2, Publications by Type and Discipline

	Business	Computing
Magazines	7	3
Peer Reviewed	5	13

2.1 Key Themes

A significant proportion of the blockchain literature focusses upon its application within cryptocurrency management, particularly Bitcoin (Chuen, 2016; Zhand and Wen, 2015; Biekverdi and JooSeok, 2015; Edwards, 2015; Di Battista et al, 2015; Barkatullah and Hanke, 2015; Ziegeldorf et al, 2015; Tsukerman, 2015; Khan, 2015; Roth, 2015; Bradbury, 2015; Anish Dev, 2014; DeWaal and Dempsey, 2014; Greebel, Moriarty, Callaway and Xethalis, 2014; Bradbury, 2014; Feld, Schonfeld and Werner, 2014; Bitcoin Theft, 2013; Bradbury, 2013; Moser, Bohme and Breuker, 2013). This literature arises predominantly in the business management field and the discussions highlight several significant concerns around cryptocurrencies including their volatility (Chen, 2016; Feld, Schonfeld and Werner, 2014), the appearance of new legislation (DeWaal and Dempsey, 2015; Greebel, Moriarty, Callaway and Xethalis, 2014), the benefits and concerns around trader and miner anonymity (Ziegeldorf et al, 2015; Bradbury, 2014) and system vulnerabilities (Khan, 2015; Tsukerman, 2015; Feld, Schonfeld and Werner, 2014; Bitcoin Theft, 2013; Network Security, 2013; Bradbury, 2013; Moser, Bohme and Breuker, 2013).

There is a smaller body of literature that focusses exclusively upon blockchain technologies that has predominantly emerged from the computing field. Some of this literature discusses current and future applications of blockchain technologies and techniques (Zhang and Wen, 2015; Zyskind, Nathan and Pentland, 2015; Kishigami, et al, 2015; Swan, 2015; Maxwell, Speed and Campbell, 2015; Coeckelbergh and Reijers, 2015; Network Security, 2013), security issues (Luu, Teutsch, Kulkarni and Saxena, 2015; Network Security, 2013), quality checking and analytical tools (Di Battista et al, 2015; van den Hoof, Kaashoek and Zeldovich, 2014) along with the limits of current technologies (Decker and Wattenhofer, 2015) and future potential trends (Beikverdi and JooSeok, 2015).

An issue that has been recognised within both the business and computing related literatures is that of the computational requirements of blockchain and the demands for power that it generates. Chuen (2016) discusses how mining remuneration may need to be constrained in order to control the growth of mining conglomerates that consume increasingly large amounts of power. Deliberately generating large numbers of very small transactions has even been identified as one way by which the blockchain system could be brought to a crawl (Network Security, 2013). The demand for increased computational power has driven developments in microchip technology to enable ever faster rates of mining (Anish Dev, 2014), however, recent rises in the cost of electricity have forced some miners to switch off their equipment until the value of Bitcoin rises to a point where it is once more economical to operate. It is tempting to overlook the cost of powering mining in blockchain activities but it is not a trivial amount: calculating a single Bitcoin transaction was estimated to cost the equivalent of 16 gallons of petrol in 2014 (Bradbury 2015).

Aside from underpinning cryptocurrency transactions, blockchain has been proposed as a technique that can facilitate other novel business and societal relations. It may be used as an escrow system for art or blueprints (Khan, 2015), as a replacement for the current forms of digital certificates (Network Security, 2013), for recording property sales including land or cars, for voting, along with the transfer of stocks, bonds, equities contracts, titles, mortgages and as a form of key (Tsukerman, 2015), for payment of medical treatment only after recovery was satisfactory and even for the illicit payment of ransom monies (Maxwell, Speed and Campbell, 2015). In addition, it has been suggested that it could be used for encoding and recording personal and incidental messages and information, however, this is a poor use of the technique that is more resource hungry than alternative, existing methods of data storage (Bradbury, 2015).

3 Summary

While the potential of blockchain technologies and techniques appear exciting and promise to make radical changes to the way that business and even society (Coeckelbergh and Reijers, 2015) are conducted, its barriers are significant. Security concerns, technical limitations, growth and sustainability, as well as environmental impact are all constraining or preventive factors. At present the blockchain literature exhibits a somewhat limited binary perspective. The scholarly literature is dominated by conceptual analyses of its computational methods and requirements while the practitioner literature rebounds between reports of the problems associated with current applications and 'crystal ball' predictions of the radical possibilities that it affords.

Blockchain may be conceptualised as a DI, however, its practical application is, as yet, rather limited and the actual impact of the approach remains to be seen. Indeed, Meade (1998) warns against making technological forecasts as many have failed to live up to the hype and eventually subsided. Contrastingly though, many new technologies that have been disregarded have since gone on to great success, such as the introduction of the Apple iPhone (Spoonaur, 2013). Despite the challenges associated with predictive research, technological forecasting and foresight analysis are becoming increasingly important tools in the armory of modern research and management (Carbonell, Sanchez-Esguevillas, and Carro, 2015; Gary and von der Gracht, 2015; Castorena, Rivera and Gonzalez, 2013; Farrington, Henson and Crews, 2012; Magruic, 2011; Dana and Guido, 2009). Consequently, this study aims to address the gap in current knowledge by making a substantiated examination of the potential applications of blockchain. It makes a further contribution by adding to the extremely limited body of literature that examines its application from a business management perspective.

4. Methodology

In the absence of substantial empirical evidence, this research employed a Delphi study to elicit expert insight into the future applications of blockchain (Kosow and Gassner, 2008; Skulmoski, Hartman and Krahn, 2007; Linstone and Turoff, 1975). Delphi studies are frequently employed in deductive research but may be combined with qualitative data capturing elements in order to afford more pragmatic instrumentalisation (Rowe and Wright, 1999). This can enable methodological triangulation (Yin, 2003), improve validity (de Vos, 1998) and increase the contextual understanding of phenomena (Jick, 1979).

The Delphi technique has been used in a wide range of research since its development in the 1950s (Dalkey and Helmer, 1963). In the field of business and management it has been employed in the study of marketing (Knutson et al, 2004; Larreche and Montgomerey, 1977), tourism (Muller, 2005; Yong, Keng and Leng, 1988), supply chain management (Melnyk et al, 2009; Lummus, Vokurka and Duclos, 2005), business improvement (Harer, 2003; Ray and Sahu, 1989), knowledge management (Scholl, Konig, Meyer and Heisig, 2004), project management (Brill, Bishop and Walker, 2006), employee and public relations (Watson, 2008; Wiggington, 1979), and extensively in information systems and technologies (Hong, Trimi, Kim and Hyun, 2015; Huang, Wu and Chen, 2013; Liu, Zhang and Chen, 2010; Bradley and Stewart, 2003; Kell, Tiwana and Bush, 2002; Schmidt, Lyytinen, Keil and Cule, 2001; Koskiala and Huhtanen, 1989). It is a particularly useful technique for gaining insight into complex phenomena where there is controversy, an absence of data, or future predictions are being made (Kosow and Gassner, 2008; Petry, 2007; Skulmoski, 2007; Mitchell, 1992; Paliwoda, 1983).

Despite its apparent usefulness, the Delphi technique presents some challenges. These include the selection of appropriate expert panel members, maintaining panel members' commitment and response rates, designing the initial survey questions and determining when a satisfactory level of agreement among the panel has been reached (Okoli and Pawlowski, 2004; Wentholt and Frewer, 2010; Brill, Bishop and Walker, 2006; Paliwoda, 1983). However, note that it is not always the intention to achieve agreement or consensus when employing the Delphi technique (Engelke, Mauksch, Darkow and von der Gracht, 2016). Furthermore, there is a lack of agreement about how many rounds should be included in an effective Delphi study (Wentholt and Frewer, 2010; Petry, Maes and Vlaskamp, 2007) but two are considered adequate (Gary and von der Gracht, 2015; Boulkedid et al, 2011; Duncan, 1995) as the addition of further rounds adds administrative burden and places pressure upon participants that results in lower response rates (Gary and von der Gracht, 2015). Data analysis methods vary but commonly rely upon the examination of descriptive statistics of the data that has been obtained within each round (Watson, 2008; Scholl, Konig, Meyer and Heisig, 2004; Harer, 2003). More sophisticated techniques, such as Kendall's W that is used in this study, can be employed to provide a more precise analysis of the changes that occur between rounds (Melnyk et al, 2009; Ray and Sahu, 1990).

This study utilized a two-round Delphi study of the views of business management scholars and expert practitioners in order to gain their views on "*how blockchain may be expected to change the future of business?*". Descriptive statistics were used to make comparative analyses of responses and Kendall's W was employed to measure the degree of concordance of the rankings in each round, where $W=0$ indicates no level of agreement and $W=1$ indicates complete agreement (Okoli and Pawlowski, 2004). There is no universally agreed value of W that indicates an 'acceptable' level of concordance but it may be used as a comparative indicator among sequential rounds of a Delphi study. The population from which the expert panel were drawn comprised academics and expert practitioners that were active members of three independent research groups based in three universities in the United Kingdom. The academics were all Senior Lecturers or Professors in a business management discipline and the expert practitioners were departmental or functional managers of UK based organisations across the public sector and a range of commercial sectors. In total, the first-round questionnaires were distributed to ninety individuals (60 academics, 30 expert practitioners). One week prior to distribution of the questionnaire, the respondents were provided with background reading in order that they may familiarise themselves with blockchain: in the absence of 'general knowledge' about blockchain this was deemed an essential element of the research protocol. Background reading consisted of a single academic article (Tsukerman, 2015) and a Youtube video (https://www.youtube.com/watch?v=YIVAluSL9SU), both subjectively selected for their clear overview of blockchain and discussions of its potential and limitations.

The questionnaires were developed from the literature review and consisted of four parts: part one identified the area of expertise of the respondent, part two required respondents to rank the likelihood of example blockchain applications being implemented (see Table 3), part three required respondents to rank the impact of the blockchain applications if they were implemented, part four was an open-ended question where respondents were encouraged to identify ways in which blockchain technologies may be employed within their reported discipline. Parts two and three were ranked on a scale of 1 to 7, where 1 indicated 'most likely' or 'greatest impact' and 7 indicated 'least likely' or 'least impact'.

Table 3, Predicted Blockchain Applications

Application	Literature
Replacing Physical Currency	Chuen, 2016; Zhang and Wen, 2015; Biekverdi and JooSeok, 2015; Edwards, 2015; Di Battista et al, 2015; Barkatullah and Hanke, 2015; Ziegeldorf et al, 2015; Tsukerman, 2015; Khan, 2015; Roth, 2015; Bradbury, 2015; Anish Dev, 2014; DeWaal and Dempsey, 2014; Greebel, Moriarty, Callaway and Xethalis, 2014; Bradbury, 2014; Feld, Schonfeld and Werner, 2014; Bitcoin Theft, 2013; Bradbury, 2013; Moser, Bohme and Breuker, 2013).
Digital Certificates	Network Security, 2013
Escrow Service (for goods)	Khan, 2015
Transfer of Bonds, Deeds or Stocks	Tsukerman, 2015
Payment of Medical Bills	Maxwell, Speed and Campbell, 2015
Register of Electronic Voting	Bradbury, 2015
Recording Personal, Private Data	Campbell, 2015

Questionnaires were distributed by email and were formatted so that respondents provided their answers to each question and clicked 'Reply' to return their completed survey. This was utilised in order to minimise costs, respondent administrative burden and improve response rates (Gary and von der Gracht, 2015; Michaelidou and Dibb, 2006; Jones and Pitt, 1999). Follow-up emails were sent each week for three weeks following the initial distribution of questionnaires. After one month a total of nine completed responses were received from academics only (10% response rate). Poor rate of response is a frequent limitation to survey research, with results ranging from 3% to over 50% (Ranchhod and Zhou, 2001). The novelty of the blockchain subject area and subsequent need to engage with the background reading may have been be significant contributors to a reduced rate of response, although 10% return is not exceptionally low. Respondents identified themselves as belonging to several key areas of business management comprising 'information technology management' (1), 'marketing' (1), 'strategic management' (2), 'human resources' (1) and supply chain management' (3). One respondent identified themselves as a specialist in 'artificial intelligence'.

Round two comprised questionnaires that were formatted similarly to those used in round one. Responses to the open-ended question four used in round were used to augment the list of predicted blockchain applications (Table 5). Respondents were again required to rank the likelihood of implementation and resultant impact of the example blockchain applications (from 1 to 14). Questionnaires were sent only to those that had completed round one.

Following round two, a series of short interviews were conducted with each respondent to elicit further detail about their expectations of the potential application and impact of blockchain applications. Interviews are particularly useful and enlightening when gathering information about an individual's position (Denscombe, 2010; Fox, 2009). In the analysis section pertinent discussions are illustrated with key phrases and all responses are anonymized.

5. Analysis and Discussion

5.1 Round One

Round One's exploration of the likelihood of implementation of the proposed blockchain applications returned a relatively low degree of concordance (W = 0.1). The 'transfer of bonds deeds or stocks' was deemed the most likely application of blockchain technologies (Mean response = 3.22) closely followed by 'digital certificates' (Mean = 3.33). Third was the replacement of 'physical currency' (Mean = 3.67) and fourth was as a 'register of electronic voting' (Mean = 3.78). The least likely implementations of blockchain were perceived to be as an 'escrow service' (Mean = 4.11), for the 'payment of medical bills' (Mean = 4.89) and for 'recording personal, private data' (Mean = 5.00). There were no marked differences between the responses of the expert panel members.

The analysis of the respondents' predictions of the impact of implementation of the proposed blockchain applications returned a higher degree of concordance (W = 0.23). Highest among these was the expected impact of the replacement of 'physical currency' (Mean = 2.0). The next most influential application, and ranked considerably lower, was the 'transfer of bonds deeds or stocks' (Mean = 3.44). Following this, the potential impact of several proposed applications were ranked similarly; 'payment of medical bills' (Mean = 4.00), 'escrow service' (Mean = 4.22), as a 'register of electronic voting' (Mean = 4.44) and for 'recording personal, private data' (Mean = 4.67). The application with the least expected impact was for 'digital certificates' (Mean = 5.22).

Table 4, Comparison of Application and Impact

Likelihood	**Rank**	**Impact**
Transfer of Bonds, Deeds or Stocks	High	Physical Currency
Digital Certificates		Transfer of Bonds, Deeds or Stocks
Physical Currency		Payment of Medical Bills
Register of Electronic Voting		Escrow
Escrow		Register of Electronic Voting
Payment of Medical Bills		Recording Personal, Private Data
Recording Personal, Private Data	Low	Digital Certificates

It is notable that two of the three applications that are considered the most likely to be implemented are also two that are considered to have the greatest potential impact ('physical currency' and 'transfer of bonds, deeds and stocks', see Table 4). In many ways the two applications can be viewed to be very similar forms of transactions: the exchange of ownership of some tangible artefact, indicated by the exchange of another (money or documentation). Since cryptocurrencies, such as Bitcoin, have become relatively well known, it is therefore unsurprising that these two applications are viewed similarly in terms of their likelihood of further implementation. The replacement of physical coinage with virtual payments, 'chip and pin' and payment with proximity devices has already made material difference to the way that goods and services are paid for, and this may influence the degree to which its further impact in the future is perceived. Contrastingly, the validation of 'digital certificates' is deemed to have a low potential impact but high likelihood of implementation. This may be interpreted as being biased due to the low number of technology-savvy experts in the Delphi panel, but the two respondents with information technology backgrounds and experiences also ranked this as sixth and seventh in the significance of its impact.

The respondents' answers to part four of the questionnaire, to identify ways in which blockchain technologies may be employed within their stated discipline, revealed a wide range of potential applications. These suggestions were incorporated into round two of the Delphi study discussed below and shown in Table 5: new suggestions were interlaced with the potential applications that were previously identified from the literature to avoid any bias through grouping predicted and proposed applications together. The expert panel appear to have been particularly drawn to the level of transparency and reliability that blockchain techniques afford. That is, once information has been encoded into the blockchain it is extremely difficult, if not impossible, to repudiate the occurrence of some transaction or event, and the multiple, independent verifications of claimed events or transactions affords a high degree of trustworthiness. In total, seven novel blockchain applications were proposed by the panel -

Independent Certification of Product Quality: Product quality assurance is a perennial issue for many organisations and a variety of mandatory and voluntary systems exist that aim to assure products and services, often via certification and labelling (see for example Ahn, 2014). A panel member stated,

> *This could overcome issue over product authenticity as well as deliver greater transparency in certification systems such as Fairtrade.*

Questions often arise over the trustworthiness of certification bodies (Dranove and Jin, 2010) and the cost of systems of certification (White and Samuel, 2015). Blockchain techniques may offer a mechanism for collating and verifying audit information.

Verified Consumer Reviews: online review of places and products have grown in use and popularity but have been lambasted for their inability to distinguish between genuine and falsified reporting (Wang, Wezel and Forgues, 2016; Scott and Orlikowski, 2014). The multiple independent verification process within blockchain may afford some greater degree of trustworthiness of consumer reviews.

Verified Corporate Due Diligence: appropriate data retrieval, analysis and transparency are prerequisites of successful mergers and acquisitions, not only for the future good of the organisation but also for the security of other investors and stakeholders (Grime and Guo, 2009). Blockchain may be capable of providing a record that suitable measures are being taken in order to assure that due diligence has been applied. A panel member stated,

> *One of the documented problems of short term strategic alliances, if not covered by formal contracts, is ownership of IP when the alliance ends*

Record of Contribution to Collaborative Initiatives: there are many different local, national and international systems of innovation that aim to foster increased collaboration and economic growth (Watkins, Papaioannou, Mugwagwa and Kale, 2015; Malik, 2013; Guan and Chen, 2012; Chaminade, Intarakumnerd and Sapprasert, 2012). While the challenges to successful cooperation are many, establishing the contribution of partners is one aspect of increasing concern (Massaini and Oliva, 2015; Li, Zhou and Zajaz, 2009) and is one that may be addressed by using blockchain techniques to embed evidence of partner inputs. A panel member stated,

> [blockchain] *could be used to verify and substantiate financial performance and claims made by organisations going through merger/acquisition activities*

Performance Management Systems: the establishment of effective performance management systems is an important part of many organisations (Church, Ginther, Levine and Rotolo, 2015). The principles of blockchain may support the development of such systems, particularly in situations where the transparency of initiatives and results is important (Mihaiu, 2014). A panel member stated,

> *The transparency afforded by this technique could alleviate any suspicions of inequity.*

Employee Voice Mechanisms: it is increasingly realised that employee effectiveness can be increased through improving their voice mechanisms (Rees, Alfes and Gatenby, 2013) but that concerns over being identified as a 'whistleblower' are serious impediments to the development of such mechanisms (Milliken, Schipani and Prado, 2015). Blockchain principles may not only facilitate such anonymous systems but may also be useful in recording organisations' responses to records of grievance.

Global Supply Chain Management: similar to the issues discussed under *Record of Contribution to Collaborative Initiatives* supply chains may benefit through the transparent sharing of vital information (Chong, Chan, Goh and Tiwari, 2013; Steinfield, Markus and Wigand, 2011). Panel members stated,

> *…it could be the real first opportunity for real SCM information tracking as no one in the chain currently owns/controls it.*

> *…it will have an impact on supplier evaluation and selection processes.*

A blockchain could be built that recorded the information sharing and production activities of supply chains and networks, independently verified by the supply chain members. In addition, it may be used to track and record global shipments or be used in the establishment of cyber-secure supply chains – this study has in fact instigated further research in this area.

Table 5, Augmented List of Blockchain Applications

Application	Source
Replacing Physical Currency	Chuen, 2016; Zhang and Wen, 2015; Biekverdi and JooSeok, 2015; Edwards, 2015; Di Battista et al, 2015; Barkatullah and Hanke, 2015; Ziegeldorf et al, 2015; Tsukerman, 2015; Khan, 2015; Roth, 2015; Bradbury, 2015; Anish Dev, 2014; DeWaal and Dempsey, 2014; Greebel, Moriarty, Callaway and Xethalis, 2014; Bradbury, 2014; Feld, Schonfeld and Werner, 2014; Bitcoin Theft, 2013; Bradbury, 2013; Moser, Bohme and Breuker, 2013).

Independent Certification of Product Quality	Round One Responses
Digital Certificates	Network Security, 2013
Verified Consumer Reviews	Round One Responses
Escrow Service (for goods)	Khan, 2015
Verified Corporate Due Diligence	Round One Responses
Transfer of Bonds, Deeds or Stocks	Tsukerman, 2015
Record of Contribution to Collaborative Initiatives	Round One Responses
Payment of Medical Bills	Maxwell, Speed and Campbell, 2015
Performance Management Systems	Round One Responses
Register of Electronic Voting	Bradbury, 2015
Employee Voice Mechanisms	Round One Responses
Recording Personal, Private Data	Campbell, 2015
Global Supply Chain Management	Round One Responses

5.2 Round Two

There was a higher degree of concordance (W = 0.21) around the likelihood of the implementation of the augmented list of fourteen applications compared to that found in round one (W = 0.1). Again the most likely application of blockchain was considered to be for the 'transfer of bonds, deeds or stocks' (Mean = 3.78). The analysis of the perceived impact (W = 0.24) of the augmented list of applications returned a similar degree of concordance to that found in round one (W = 0.23). Table 6 presents the Mean values for the implementation and impact of the augmented list of applications.

Table 6, Comparison of Augmented List of Blockchain Applications

Likelihood	Mean	Rank	Mean	Impact
Transfer of Bonds, Deeds or Stocks	3.78	High	3.78	Physical Currency
Digital Certificates	5.33		5.44	Payment of Medical Bills
Physical Currency	5.33		5.67	Transfer of Bonds. Deeds or Stocks
Register of Electronic Voting	6.22		5.78	Global Supply Chain Management
Independent Certification of Product Quality	6.44		6.00	Escrow
Record of Contribution to Collaborative Initiatives	6.89		7.22	Recording Personal, Private Data
Verified Consumer Reviews	7.00		7.56	Record of Contribution to Collaborative Initiatives
Global Supply Chain Management	8.00		7.67	Verified Corporate Due Diligence

Recording Personal, Private Data	8.89		8.22	Register of Electronic Voting
Payment of Medical Bills	9.00		8.56	Digital Certificates
Escrow	9.00		8.67	Employee Voice Mechanisms
Employee Voice Mechanisms	9.33		8.89	Independent Certification of Product Quality
Performance Management Systems	9.44		9.67	Performance Management Systems
Verified Corporate Due Diligence	10.33	Low	11.89	Verified Consumer Reviews

It is pertinent to note that the top three blockchain applications, both in terms of their perceived likelihood of implementation and impact, are ones that had been previously identified within the literature. Furthermore, the bottom three blockchain applications are among those novel applications that had been identified by the Delphi panel in round one. This may be due to the panel's lack of familiarity with some of the new applications that had been proposed. The fourth most significant blockchain application, in terms of its potential impact, was perceived to be 'Global Supply Chain Management' and its relatively high ranking among the panel may be accounted for by the fact that three of the panel identified themselves as experts in the area of 'Supply Chain Management'.

The relative ranking of the seven initial blockchain applications, identified from the literature, did not change significantly when they were ranked among the augmented list of applications (see Table 7). In round two there was a notably higher degree of concordance (W = 0.28) around the likelihood of implementation of these applications than was recorded in round one (W = 0.1). In both rounds the 'transfer of bonds, deeds and stocks' was considered to be the most likely application of blockchain to be implemented. 'Digital certificates' was ranked second most likely in round one and third most likely in round two, while 'physical currency' was third most likely in round one and third most likely in round two. 'Register of electronic voting' was considered fourth most likely application in both rounds one and two. 'Escrow' was ranked fifth in round one and sixth in round two, and 'payment of medical bills' was ranked sixth in round one and fifth in round two. In both rounds 'recording of personal private data' was ranked seventh.

However, while round two exhibited a similar degree of concordance (W = 0.2) around the impact of application of applications to that recorded in round one (W = 0.23) there are some slight differences in the relative ranking of some of the applications between each round. In both rounds 'physical currency' was considered to have the most significant impact. The 'transfer of bonds, deeds and stocks' was ranked second in round one and fourth in round two. The 'payment of medical bills' remained reasonably consistent, being ranked third in round one and second in round two. 'Escrow' was ranked fourth most significant impact in round one and second in round two. 'Register of electronic voting' was ranked fifth in round one and sixth in round two, and 'recording personal private data' was ranked sixth in round one and fifth in round two. As previously discussed, the ranking of 'escrow' and the 'transfer of bonds deeds and stocks' changed between rounds, particularly when one considers that the applications are rather similar. This may be due to interpretation of the terms but such interpretation could be expected to be consistent between rounds.

Table 7, Relative Ranking of Initial Applications in Round Two

Likelihood	**Mean**	**Rank**	**Mean**	**Impact**

Transfer of Bonds, Deeds or Stocks	2.33	High	2.22	Physical Currency
Physical Currency	3.00		3.67	Escrow
Digital Certificates	3.44		3.67	Payment of Medical Bills
Register of Electronic Voting	3.89		3.78	Transfer of Bonds, Deeds or Stocks
Payment of Medical Bills	5.00		4.56	Recording Personal Private Data
Escrow	5.11		4.89	Register of Electronic Voting
Recording Personal Private Data	5.22	Low	5.22	Digital Certificates

5.3 Summary

The analyses of blockchain applications according to their perceived likelihood of implementation and potential impact are useful in several ways. Perceptions of their likelihood of implementation may give some indication to business owners or managers about how they should account for these applications in their strategizing process. For instance, the possibility that cryptocurrencies may supplant tangible currency, or at least offer a secure and transparent alternative to them, would undoubtedly have a significant impact upon any organisation's finance and information technology strategies. Similarly, perceptions of the impact of implementation of applications may be indicators of areas of necessary future research. For example, the payment of medical bills only after successful treatment has been received would have considerable consequences for medical practice and ethics. One can compare the current situation in many countries where medical assistance is provided in order to relieve the sufferer of the current malady, that is, medics are remunerated in order to relive or prevent a 'higher order' medical condition such as gross infection or death. Such a system may be described as being 'paid for not being dead', that is, the sufferer may well be left with some 'lower order' remnant of the condition such as an infirmity. However, should a system be implemented that required successful treatment to be given in order for remuneration to be made then one could argue should a sufferer be left with some lower order condition as a result of being treated for a higher order condition then they may claim that they have not been 'cured'. Such a system could be termed 'not paid for not being cured'. The ethical and legal ramifications of such a change in system are likely to be considerable and require focussed scholarly and expert attention before implementation. Cortez (2014) for example, warns of the long-term paralysing effects that misguided regulatory pressures can place upon disruptive innovations.

In order to consolidate the augmented list of blockchain applications, hitherto separately ranked according to likelihood and impact of implementation, this study draws upon the method for calculating Rank Priority Numbers (RPN) in the completion of Failure Mode Effects Analyses (FMEA) (see for example, Liu, You, Ding and Su, 2015). Table 8 presents the consolidated ranking of the augmented applications, produced by multiplication of the mean ranking for likelihood (L_M) with the mean ranking for impact (I_M) of each application.

There is some suggestion that the consolidated rankings fall into three discernible groups. 'Physical currency' and 'transfer of bonds, deeds or stocks' exhibit markedly lower scores (L_M x I_M = 20.15 and 21.41) than the next group. This would indicate that these applications, that are already in existence to some degree, are likely to experience increased growth. These are areas where businesses need to plan to incorporate these techniques in order to gain and maintain competitive advantage. It is possible that late adopters may benefit from the maturation of the underlying technologies that in turn results in a less risky implementation of disruptive innovations (Carlo, Gaskin, Lyttinen and Rose, 2014). Indeed, Gilbert (2003) adopts a brighter perspective of the challenges presented by DIs. In contrast to the established view of many, that DIs are threats to be guarded against, he views them as opportunities to be embraced.

The next group of results, comprising 'digital certificates' to 'recording personal and private data' ($L_M \times I_M$ = 45.63 to 64.20), would appear to be areas where the usefulness of blockchain applications is less certain. These are areas that would benefit from increased scholarly and expert practitioner attention to further understand the benefits and barriers of development and adoption.

The final group of results, comprising 'verified corporate due diligence' to 'performance management systems' ($L_M \times I_M$ = 79.22 to 91.30), are areas where implementation is unlikely, or equally possibly, that the benefits and impact of the applications are appreciable only to those that are experts in that field. These potential applications require careful consideration to identify which applications may be commercialisable. This is perhaps an area where smaller technology companies have an advantage in being able to operationalize disruptive innovations, such as blockchain, into saleable products and services (Carayannopoulos, 2009) and even established corporations may benefit if they embrace the opportunity rather than fear the challenge (Gilbert, 2003).

Table 8, Consolidated Ranking of Augmented List of Blockchain Applications

Application	**$L_M \times I_M$**
Physical Currency	20.15
Transfer of Bonds, Deeds or Stocks	21.41
Digital Certificates	45.63
Global Supply Chain Management	46.22
Payment of Medical Bills	49.00
Register of Electronic Voting	51.16
Record of Contribution to Collaborative Initiatives	52.05
Escrow	54.00
Independent Certification of Product Quality	57.28
Recording Personal Private Data	64.20
Verified Corporate Due Diligence	79.22
Employee Voice Mechanisms	80.89
Verified Consumer Reviews	83.22
Performance Management Systems	91.30

6. Conclusion

This paper is guided by the broad question "*how blockchain may be expected to change the future of business?*" and provides understanding by eliciting the insight of an expert panel through the use of a Delphi study. Drawing upon the limited extant literature it analyses the likelihood and impact of current proposed blockchain applications before identifying and examining further novel uses.

The study is the first to provide a substantiated analysis of future potential applications of blockchain techniques. It makes a contribution to the limited literature that considers the application of blockchain within business and management. It proffers a hierarchy of applications identifying those that are likely to see continued growth, those that require further analysis of their benefits and barriers, and those that are considered unlikely to come to fruition.

However, it is noted that less likely applications should not be discarded, rather they require more concerted examination.

Business managers need to be aware of the potential impact of blockchain techniques. It is already underpinning the continual shift toward the ubiquitous adoption of cryptocurrencies. This study has outlined numerous ways in which it may further shape internal business processes, the connectivity of entire supply chains and offer opportunities to develop new markets and offerings. However, organisations must be wary of engaging in "*rampant experimentation*" (Porter, 2001, 3) during the early stages of the development of these technologies.

Blockchain also offers considerable opportunities for application developers. This study has identified areas where the technique may be employed in developing innovative and valuable new business processes and products. Companies that are able to incorporate the approach and take advantage of its unique characteristics, such as being able to replace trust-based systems, could create and exploit lucrative markets.

This study is constrained by several factors. Firstly, the study has focused upon exploring the impact of blockchain within the business management discipline. Other potential applications may be identified by adopting a different frame of reference. Secondly, the relatively low rate of response has narrowed the examination of future applications. Larger samples would be desirable, although very large studies may more effectively employ other forms of survey strategy rather than the Delphi technique. Thirdly, at present the concept of blockchain is not well known and the underlying technology may be challenging for business management scholars and practitioners to comprehend. This may have contributed to a relatively low rate of response. Furthermore, lack of knowledge of blockchain principles may have limited the ability of panel members to envision future applications and the findings may therefore be correspondingly conservative. Future studies may benefit by drawing upon experts from within the computing discipline and combining their insight with those from business management.

Given the potential impact of blockchain technologies and the rareness of knowledge about it, efforts should be made to improve the awareness of scholars and business practitioners. Dissemination should take place through academic output, practitioner workshops and business conferences.

Future research should examine the development and impact of blockchain. The benefits and barriers to its adoption will require better understanding and useful insight may be gained through exploring the characteristics and rate of its diffusion. Some applications of blockchain have the potential to radically alter aspects of society and the legal and ethical ramifications of such developments need due consideration before and during their implementation.

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