Barriers to SMEs Adoption of Big Data Analytics for Competitive Advantage

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Abstract— **Small and medium-sized enterprises (SMEs) (which includes micro companies employing < 10) make a significant contribution to the UK economy accounting for 99.9% of all businesses, employing 60% of the work force and generates £2,168 billion; this represents 52% of the turnover of all businesses in the UK [1]. Big Data Analytics is rapidly being utilised by large companies on a global scale to gain competitive advantage which is well documented in the literature. However, the evidence from the literature indicates that SMEs are underutilising this technology for a variety of reasons, for example lack of expertise and cost implications. The intention of this paper is to identify barriers to the adoption of Big Data Analytics by SMEs to help them overcome the challenges and to exploit the benefits of Big Data Analytics to improve their competitive advantage which will benefit the wealth of the country particularly in the aftermath of Covid-19.**

Keywords—Big Data, Big Data Analytics, SMEs, Barriers to Big Data Analytics Adoption, Competitive Advantage, Covid-19

I. Introduction

The adoption of Big Data Analytics by SMEs is extremely limited [2] despite the competitive advantages they could achieve. Examples cited include the reduction of a product development lifecycle by over 7 months and reducing the cost of product development by 90% [3]. The literature relating to SMEs and the adoption of Big Data Analytics is currently limited [4] despite the fact that SMEs generate half of the turnover of the UK's private sector (£2,168 billion) [1]. The economic contribution of SMEs and the possible benefits to SMEs of adopting Big Data Analytics mean that it is important to investigate the factors affecting the adoption of Big Data Analytics by SMEs. The paper is organised as follows: Section 2 discusses Big Data Analytics, SMEs and how SMEs can adopt this technology. Section 3 discusses how a literature review was undertaken to identify barriers to SMEs adopting Big Data Analytics. Section 4 describes a Thematic Analysis process to produce a refined list of barriers, Section 5 describes the refined list and Section 6 discusses future work and concludes the paper.

II. Big Data Analytics and SMEs

Willetts et al. [5, p. 3034] defines Big Data as: 'an umbrella term used to describe a wide range of technologies that capture, store, transform and analyse complex data sets which can be of a high volume, generated at a high velocity in a variety of formats'. However, there is no agreed definition for Big Data [6]. It has been suggested that Big Data has three characteristics: volume, velocity and variety [7]. The variety of Big Data refers to the variety of data sources including structured data, such as data stored in a database management system and unstructured data which includes email messages, social media posts, pictures and videos [8]. Big Data sources can also include semi-structured data, such as XML (Extensible Mark-up Language) documents [9].

Saggi and Jain [10] define three categories of Big Data: machine-generated data which originates from sources including computer networks, sensors, satellites, audio, video and streaming; human-generated data in the form of identification data and social media content; and business-generated data in the form of transactional, corporate and government agencies' data. IoT (Internet of Things) and Smart devices, including Smartphones are one of the prominent drivers for Big Data, each typically contain digital sensors capable of capturing data, including cameras, audio recorders, compasses, gyroscopes, accelerometers and GPS locators [6].

Big Data Analytics refers to the variety of software tools and techniques which are used to extract insights from Big Data sources. Mikalef et al. [11, p. 262] state that a widely used definition of Big Data Analytics is: 'a new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data, by enabling high velocity capture, discovery and/or analysis.' There does not appear to be a definitive category of Big Data Analytics tools and techniques. Sivarajah et al. [12] describe five categories of Big Data Analytics: Descriptive analytics, Inquisitive analytics, Predictive analytics, Prescriptive analytics and Pre-emptive analytics. Gandomi and Haider [9] outlined several techniques for Big Data Analytics including text analytics, audio analytics, video analytics, social media analytics, and predictive analytics.

Many organisations are reporting measurable benefits from adopting the technology. Narellan Pools demonstrated that utilising Big Data Analytics to drive their marketing, resulted in an improvement of a 54:1 ratio of revenue to expenditure on media [13]. The Oil and Gas industry are utilising Big Data Analytics to reduce unplanned downtime, saving operators an average of $17 million per year [14]. United Parcel Service (UPS) have utilised Big Data Analytics to optimise its drivers routes as it was estimated that reducing drivers routes by one mile per day would save the company $50 million per year [15], this would allow small companies adopting this technology to optimise drivers' routes on a smaller scale [16].

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TABLE I. PRIVATE SECTOR BUSINESS IN THE UK 2019 [1]

	Businesses (1000s)	Employment (1000s)	Turnover (£ billions)	Businesses (%)	Employment (%)	Turnover (%)
No employees	4,458	4,835	305	76%	18%	7%
SMEs (0-250 employees)	5,860	16,630	2,168	99.9%	60%	52%
Of which: Micro (0-9 employees)	5,613	9,041	900	96%	33%	22%
Small (10-49 employees)	211	4,117	629	4%	15%	15%
Medium (50-249 employees)	36	3,473	639	1%	13%	15%
Large (250+ employees)	8	10,868	1,982	0%	40%	48%
Total, all businesses	5,868	27,498	4,150	100%	100%	100%

Table I indicates that a small company (0-49 employees) is one which meets at least two of the following criteria [17]: a turnover of less than £10.2 million; £5.1 million or less on its balance sheet; or employs less than 51 people. A medium-sized company in the UK is classified by meeting at least two of the following criteria: an annual turnover of £36 million or less; a maximum balance sheet total of £18 million; or a maximum of 250 employees [18]. A company would be classified as large if it exceeded these criteria. SME's comprise 99.9% of all businesses in the UK and provides 60% of employment [1], therefore assisting them to gain competitive advantage through the adoption of technology is extremely important. SMEs comprise 99.8% of businesses in the EU's non-financial sector [19] and 90% of all businesses worldwide [20].

Mattera [21] states that despite some Big Data tools being complex and too costly for SMEs, free tools such as Google Analytics are available which could be adopted by SMEs. In a focus group of SMEs based on the Spanish restaurant industry, the respondents were mostly unaware of the low cost or free Big Data tools available and once learning what they were, expressed interest in using them, suggesting that awareness is also a barrier to adoption [21]. However, there are case studies available of SMEs who have adopted Big Data Analytics [3], [16].

III. LITERATURE REVIEW OF BARRIERS TO BIG DATA ANALYTICS ADOPTION

A literature search was undertaken to identify the barriers SMEs encounter when adopting Big Data Analytics. As the majority of Big Data literature relates to larger companies, the literature relating to both SMEs and large companies was reviewed. Although there may be factors which are specific to SMEs, it is likely that adoption barriers which impact large companies would also be applicable to SMEs, including skills and the technology required. The search terms and results are listed in Table II for the searches conducted in June 2020. A range of search terms was used as it was expected that different words may be used to classify barriers, for example they could be classified as issues, problems or challenges. The scope of the searches was restricted to Big Data or Big Data Analytics, to maintain relevance to the topic. The two main search engines used in the literature review were Summon and Google Scholar.

The initial search produced a very large number of hits and therefore, search 2 was refined to display results for the last five years and "SME" was added to the search criteria. An SME could be described as a "small business" or "small company" therefore these were included within the search terms, in addition to "micro company" and "micro companies". This second search returned 513 articles which were considered too many to review. The third search removed the terms "challenges", "issues" and "problems", to restrict the searches to "barriers" which returned 197 results which were all reviewed, as shown in Table II. Articles which were relevant to this study had to meet two criteria: they focus on the adoption of Big Data or Big Data analytics; and they list or describe barriers a business would encounter when adopting Big Data or Big Data analytics. This search which was carried out using Summon identified 10 relevant articles. Search 3 was repeated on Google Scholar, however this returned over 15,100 results, which were deemed unfeasible to review due to the limitations of this study and therefore the review was limited to the first 100 most relevant and highly cited articles returned by Google Scholar. This led to the identification of three further studies in addition to the 10 studies previously identified. Using the snowball approach, Ahmed et al [22] referenced Mcafee and Brynjolfsson's [23] on managerial challenges of Big Data was also included within the scope of this literature search.

TABLE II. BIG DATA AND BIG DATA ANALYTICS BARRIERS LITERATURE SEARCHES

No.	Search Terms	Summon	Google Scholar
1	("Big Data" OR "Big Data Analytics") AND ("issues" OR "problems" OR "challenges" OR "barriers")	28,412	18,100
2	("Big Data" OR "Big Data Analytics") AND ("issues" OR "problems" OR "challenges" OR "barriers") AND ("SME" OR "SMEs" OR "micro company" OR "micro companies" OR "small business" OR "small businesses ")	513	17,100
3	("Big Data" OR "Big Data Analytics") AND (" barriers") AND ("SME" OR "SMEs" OR "micro company" OR "micro companies" OR "small business" OR "small businesses ")	197	15,100

From the searches, 14 studies were identified, listed in Table II. Each paper was examined and the barriers to Big Data or Big Data Analytics were recorded and analysed in a spreadsheet, with an extract displayed in Table III. A total of 71 barriers to Big Data Analytics adoption was identified. Many of the barriers appeared multiple times, for example, "Shortage of In-House Data Analytic Expertise" appeared in eight articles. Some of the barriers appeared to be the same but were named differently, for example "Lack of Technical Skills" [24] or "Lack of In-house Big-Data Experts" [25].

TABLE III. LITERATURE REVIEW RESULTS FOR BIG DATA BARRIERS

Author	Year	Title	Discipline
Alharthi, Krotov and Bowman [26]	2017	Addressing barriers to big data	Big Data
Lee [27]	2017	Big data: Dimensions, evolution, impacts, and challenges	Big Data
Mcafee and Brynjolfsson [23]	2012	Spotlight on Big Data: The Management Revolution	Big Data
Sejahtera et al.[24]	2018	Enablers and Inhibitors of Effective Use of Big Data: Insights from a Case Study	Big Data
Arunachalam, Kumar and Kawalek [28]	2018	Understanding big data analytics capabilities in supply chain management: Unravelling the issues, challenges and implications for practice	Big Data Analytics
V. Ahmed *et al* [22]	2017	The future of Big Data in facilities management: opportunities and challenges	Big Data Analytics and SMEs
Polkowski And Nycz [29]	2016	Big Data Applications in SMEs	Big Data Analytics and SMEs
Bianchini and Michalkova [6]	2019	OECD SME and Entrepreneurship Papers No. 15 Data Analytics in SMEs: Trends and Policies	Big Data and SMEs
Coleman *et al.* [30]	2016	How Can SMEs Benefit from Big Data? Challenges and a Path Forward	Big Data and SMEs
Engels [31]	2017	Detours on the Path to a European Big Data Economy	Big Data and SMEs
Iqbal et al [25]	2018	A study of big data for business growth in SMEs: Opportunities & challenges	Big Data and SMEs
Noonpakdee, Phothichai and Khunkornsiri [32]	2018	Big data implementation for small and medium enterprises	Big Data and SMEs
O'Connor and Kelly [33]	2017	Facilitating knowledge management through filtered big data: SME competitiveness in an agri-food sector	Big Data and SMEs
Olufemi [34]	2018	Considerations for the Adoption of Cloud-based Big Data Analytics in Small Business Enterprises	Cloud-based Big Data Analytics and SMEs

Where barriers were named slightly differently but related to a previously recorded barrier, they were merged into the existing barrier. Two of the barriers reported by Ahmed et al. [22] were not deemed relevant to this study: "that limited access to large volumes of data by small groups in the society can create information divides or concessions" and "the widespread belief that bigger data sets are always better without giving much concern to methodological issues and data quality'". These appear to be related to ethical concerns already identified as a barrier. Removing these reduced the number of barriers to 69.

IV. THEMATIC ANALYSIS OF BIG DATA ANALYTICS ADOPTION BARRIERS

A thematic analysis is the process of identifying, analysing and reporting patterns and themes from qualitative datasets [35]. Braun and Clarke [35] describe the six phases of conducting a thematic analysis: Phase 1 Familiarisation with the data; Phase 2 Generating initial codes; Phase 3 Searching for themes; Phase 4 Reviewing themes; Phase 5 Defining and naming themes Phase 6 Producing the report.

Although, thematic analysis is commonly associated with qualitative analysis of primary data including interview transcripts, it has been utilised to review literature [36]. Two clearly documented examples were followed to conduct this analysis [35], [37]. For the First phase, Familiarisation of data, a literature search was conducted which identified 14 documents which listed barriers to Big Data Analytics for SMEs. A total of 69 barriers were identified. To ensure familiarisation was achieved, the articles were read again to ensure that the barriers were understood, reducing the risk of ambiguity and misinterpretation of meaning.

The Second phase is Generating initial codes. Codes are used to identify a feature of the data being reviewed and it is recommended that as many potential themes as possible are coded, as this may be useful later [35]. Therefore, fifteen initial codes were identified from the literature review: Business cases; Change Management; Culture; Data; Ethical; Finance; Infrastructure; Knowledge and Skills; Legislation; Management; Organisation; Privacy; Resources; Security; and Software. Each code was allocated a colour and the 69 barriers were reviewed, each highlighted in a colour matched to a relevant code.

The Third phase, Searching for themes, requires the codes from the previous phase to be arranged into potential themes. Themes capture important aspects of the data relating to the research question but there are no definitive answers as to what proportion of the dataset needs to display evidence of a theme for it to be considered as a theme [35]. Ryan and Bernard [38] state that repetition of the same concept in a text may indicate that it is a theme. Many of the barriers have similar repeated elements for example, several barriers contain the word data including "data presentation", "data scalability" and "data silos". This repetition indicates that data could be a theme. The majority of the fifteen codes were related for example infrastructure and software refer to a technical theme. Therefore, six initial themes were identified which are as follows:

- Data barriers represent issues with the data itself, for example: presenting the data, data quality, data silos, complexity of data and standards. This theme includes the barriers coded: data.
- Knowledge and skills barriers refer to the skills needed to use Big Data. As Big Data Analytics is

a relatively new technology, it is unlikely that SMEs will have the skillsets required to utilise it. This theme includes the barriers coded: knowledge and skills.

- Regulatory barriers refer to legal, ethical, privacy issues which organisations need to be aware of to ensure compliance, for example data protection legislation which dictates how businesses should store and process personal data. This theme includes the barriers coded: ethical, legislation, privacy and security.
- Technical barriers are related to the infrastructure required to facilitate Big Data Analytics. These consist of hardware and software issues, including security, data storage issues and the requirement of a high bandwidth internet connection to support Cloud-based services. This theme includes the barriers coded: infrastructure and software.
- Organisational barriers refer to the barriers present within a company to the adoption of Big Data Analytics. These refer to issues with the organisational structure, culture, top management support and the lack of a strategy. This theme includes the barriers coded: change management, culture, management and organisation.
- Resource barriers relate to the financial constraints an SME encounters. For example, the cost of procuring Big Data Analytics technology, the resources required to implement and use it and the time an SME needs to dedicate to the project. This theme includes the barriers coded business cases, finance and resources.

Each theme was allocated a colour and the barriers were highlighted to match the theme they had been assigned.

The Fourth phase requires the preliminary themes identified in the previous phase to be reviewed, modified and developed [35]. It was thought that the six themes identified accurately represented the barriers. Some of the barriers were moved from one theme to another for example some of the technical barriers were moved to the data theme. The 69 barriers were divided into: 15 data barriers, 12 knowledge and skills barriers, 5 regulatory barriers, 6 resource barriers, 11 technical barriers and 20 organisational barriers. Fig. 1 depicts the six themes identified together with 69 barriers from the literature search.

The fifth phase, defining and naming the theme is the stage in which the final revisions are made to the themes and any sub themes identified with a final thematic map created [35]. At this point, the six themes identified were clarified by re-reading the literature articles and reviewing each barrier, however they were not derived from an underpinning theoretical framework. A thematic approach is similar to a top down approach in software engineering design. Consequently, it would be appropriate to integrate the design to a bottom-up design based on theoretical concepts. Therefore, to evaluate the analysis, a suitable theoretical framework was required because a framework provides a coherent approach to organising the factors and support the evaluation. By using a theoretical basis for the development of the research framework, this research is following the programmatic research agenda, conforming to the accepted conventions of research [39].

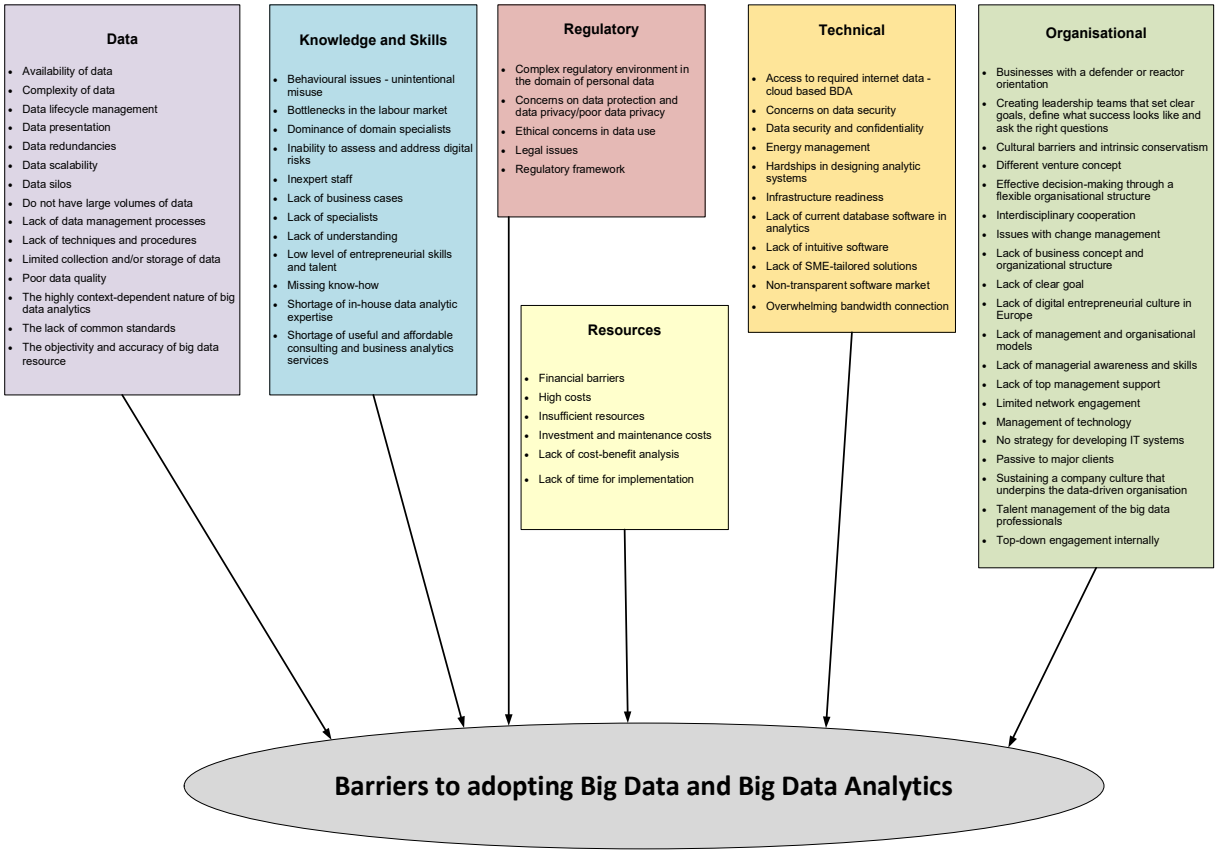

Fig. 1. Thematic map of barriers to Big Data and Big Data Analytics adoption

To provide further academic rigour to the themes which were identified from the barriers to Big Data Analytics adoption by SMEs, it was decided to utilise theoretical frameworks to theme the barriers. After undertaking a literature review of theoretical frameworks, eight frameworks were identified: TOE; Diffusion of Innovations; Institutional Theory [40];Human, Organisation, Technology-fit (HOT-fit) [41]; Resource Based View [42]; Technology Acceptance Model (TAM) [43]; Information Systems Strategy Triangle (ISST) [44]; and Task-Technology-Fit [45]. From these eight frameworks, three complementary frameworks were selected: Technology-Organization-Environment (TOE), Human, organisation, technology-fit (HOT-fit) and the Information Systems Strategy Triangle (ISST). Business factors is a key consideration for SMEs and these are only represented in the Information Systems Strategy Triangle framework. The TAM and HOT-fit frameworks represent human factors, however HOT-fit also incorporates organisational and technological factors. HOT-fit and TOE have also been combined in other Big Data adoption studies [46]. Therefore, the ISST and HOT-fit frameworks complement TOE, which was utilised in the majority of the technology adoption studies (8 out of 14) reviewed, suggesting it would be suitable for this study. The Thematic Analysis of the barriers outlined in Fig. 1 have been rearranged into five pillars based on the theoretical frameworks TOE, HOT-fit and the Information Systems Strategy Triangle. Therefore, the barriers to Big Data Analytics adoption are now classified under the categories: Technological, Human, Organisational, Environmental and Business. Technological barriers represent issues relating to the hardware and software where Big Data and Big Data Analytics solutions reside. Therefore, data related challenges including complexity, scalability and data quality that were previously classified under the "data theme" are now incorporated into the technological theme, in addition to the barriers classified in the existing "technical" theme. Human barriers relate to the knowledge and skills required to adopt and utilise Big Data Analytics. The theme "Knowledge and Skills" was created in stage three, therefore the majority of the barriers classified under this theme can be transferred to Human barriers category. The Organisational barriers refer to the challenges within an organisation of adopting Big Data Analytics, predominantly from a management perspective. These include support from the top level of management, cultural issues, change management, talent management and the management of technology itself. The Organisational theme was already created at stage three, therefore no change to this theme is required. Environmental barriers are the issues outside an organisation's control including legal, ethical, privacy and regulatory issues which must be complied with. The "Regulatory" theme barriers were transferred into the Environmental theme. Business barriers refer to financial and resourcing issues which a business may experience when adopting Big Data Analytics as time and investment will be required to implement it successfully.

The existing six themes and 69 barriers were reviewed against the chosen theoretical frameworks and from this, five pillars were derived namely: business, environmental, human, organisational, and technological respectively. Many of the 69 barriers mentioned were reoccurring barriers, therefore many of these barriers were merged and renamed. The following barriers were removed due to lack of clarity or detail in the literature:

- Passive to major clients
- Interdisciplinary cooperation
- Lack of digital entrepreneurial culture in Europe
- Low level of entrepreneurial skills and talent
- Data redundancies
- Data lifecycle management
- Difficulties in designing analytic systems

A. Business Pillar

The business pillar contains two barriers: financial barriers and lack of business cases. Financial barriers highlight the investment required to adopt Big Data. SMEs are not able to borrow large amounts of finance, therefore they are cautious investing in technologies beyond their business scope [30]. Similarly, SMEs may not have a budget for IT or Big Data investment [32]. In addition to the cost factors associated with the generation, storage, processing, analysis and interpretation of Big Data, there are also other costs including cybersecurity and training [31]. Lee [27] highlights that a major issue of adopting Big Data Analytics is investment justification, as executives may be concerned about committing to a large investment to deliver tangible benefits which are outweighed by the tangible costs, despite potential large intangible benefits being delivered.

Lack of business cases refers to the lack of success stories which document how SMEs have adopted Big Data Analytics. Although, guidance for Big Data Analytics adoption exist, there is a critical shortage of stimulating and trend-setting SME case studies [25], [30]. Case studies of businesses operating under similar limitations to themselves would be very helpful in convincing SMEs why they should adopt Big Data Analytics and providing a blueprint of how to achieve similar benefits.

B. Environmental Pillar

The Environmental pillar contains four barriers: ethical concerns; the inability to address digital risks; regulatory issues and the lack of common standards. Ethical concerns are the fears relating to the collection and usage of Big Data [22]. Big Data has been criticised for breaches of privacy for example, utilising large datasets to make predictions and generalisations to target individuals with products they did not know they needed [47]. Therefore, when businesses adopt Big Data Analytics, they need to be aware of concerns that may arise if they utilise it unethically.

The inability to assess and address digital risks refers to the lack of awareness and capability within an SME to effectively respond to external security threats, for example hacking, phishing and ransomware; if a company opens up their infrastructure to adopt new sources of Big Data, they will require security policies and procedures [6]. This suggests training or additional personnel may be required, adding to the cost of Big Data Analytics adoption.

Regulatory issues refer to the legal, security, privacy concerns of collecting data. Bianchini and Michalkova [6] reported from Eurostat that only 14% of European SMEs manage digital security and data protection internally compared with 64% of large enterprises, suggesting that this may be an issue. Big Data Analytics are likely to utilise personal data relating to an individual that was collected for a specific purpose, therefore if this is combined with other data sources there may be legal and ethical implications [26]. Lee [27, p. 301] suggests that: 'protecting privacy is often

counterproductive to both firms and customers, as big data is a key to enhanced service quality and cost reduction. Therefore, firms and customers need to strike a balance between the use of personal data for services and privacy concerns'. To comply with relevant legislation including the EU's General Data Protection Regulation, SMEs are required to have sufficient knowledge about legislation and regulation to ensure their processes cater to these requirements. Coleman et al. [30] state that the EU Handbook on European data protection law contains over 200 pages and that SMEs may not be able to afford to acquire support from lawyers to understand what the implications are for their business. Data security will likely require a review if new Big Data technologies are introduced into a business' IT infrastructure. If an SME does not have sufficient security mechanisms, confidential information could be transmitted or intercepted by unintended parties, resulting in financial loss and the business' reputation being damaged [27].

Big Data derives from many sources and is gathered and exchanged, therefore the lack of common standards refers to the absence of standardised interfaces to facilitate the transfer of data [31]. Common metadata schemas and standardised vocabularies will be required to ensure that the transfer of data is as seamless as possible but the current absence of data exchange standards are a major barrier to digital transformation [31].

C. *Human Pillar*

There are two barriers in the human pillar: lack of in-house data analytics; and shortage of consultancy services. Lack of in-house data analytics expertise is one of most significant barriers to Big Data Analytics adoption for SMEs, as this was widely cited. Eight similar barriers were merged to form lack of in-house data analytics at stage three of the thematic analysis. This barrier incorporates all of the issues relating to the lack of skills and awareness required to implement and utilise Big Data Analytics. SMEs have a very low understanding of Big Data Analytics and are therefore unlikely to adopt a technology they are unsure of [30]. Similarly, data analysts are rarely employed by SMEs and the recruitment of data scientists is currently unfeasible for SMEs due to scarcity and cost, which is a major investment for larger organisations [31]. The skillsets required for SME data science posts are more comprehensive than larger companies, as larger companies can afford to distribute responsibilities over several posts [30].

Shortage of consultancy services is a significant concern because if SMEs do not currently have the knowledge and skills in-house required to utilise Big Data Analytics, they may need to acquire the expertise externally. Iqbal et al. [25] state that SMEs do not generally hire consultants for management and business analytics. Consultancy firms commonly work with large companies on complex, time consuming projects which would be unaffordable for SMEs [25], [30].

D. *Organisational Pillar*

The organisational pillar consists of seven barriers: change management; cultural barriers; insufficient volumes of data to be analysed; lack of managerial awareness and skills; lack of top management support; the management of technology; and talent management.

The adoption of Big Data Analytics is a change management project and therefore there may be resistance to change. This was identified in a study undertaken by Schoenherr and Speier-Pero [48] focusing on Big Data and predictive analytics adoption in Supply Chain Management (SCM). Although, this barrier was only reported once in the literature review undertaken [28], it would appear to be a significant factor to address when adopting a technology which could require an organisation to make major changes to its operations.

Cultural barriers are the issues relating to an SME's mindset and internal culture. Alharthi, Krotov and Bowman [26, p. 289] state that organisational culture has a major impact on the various aspects of an organisation including its strategy, structure and processes. Therefore, the top management will implement an organisational strategy and design an organisational structure based on their beliefs of organisational values and norms [26]. SMEs are rarely interested in current management trends and are therefore likely to view Big Data Analytics as management hype rather than an opportunity [25], [30]. Similarly, organisations that are aiming to implement a data-driven culture are required to move away from making decisions entirely on hunches and instinct [23]. Therefore, changing the organisational culture may be a major barrier to Big Data Analytics adoption.

Insufficient volumes of data to be analysed highlights the issue that not all SMEs may have large volumes of data, therefore they may not perceive Big Data Analytics to be relevant. Noonpakdee, Phothichai and Khunkornsiri [32] state that some SMEs do not utilise social media and store data in paper format and spreadsheets (Excel), therefore their data does not yet have the Three V attributes [32].

Lack of managerial awareness and skills relate to SME managers and entrepreneurs not understanding the need to change traditional business practices and use Big Data Analytics to improve the business [6]. Mcafee and Brynjolfsson [23] state that companies that have leadership teams which have clear goals succeed in the Big Data era, not because they have more or better data.

Lack of top management support is a very important barrier to Big Data Analytics adoption projects, as their support is crucial to ensure that the necessary investment, resources and authority are available for Big Data Analytics adoption to be a success [24]. Olufemi [34, p. 73] found : 'that no matter how useful and cost effective an innovation might be, the lack of SMEs owner/top management support can easily obstruct the adoption of the innovation'.

The management of technology refers to the skills required to administer the hardware and software required to manage the volume, velocity and variety of Big Data [23]. Due to the introduction of new technology, the existing IT department is unlikely to have the necessary skillsets required to integrate the required internal and external data sources [23].

Talent management is the management of the technical personnel required to utilise Big Data Analytics. Mcafee and Brynjolfsson [23] state that data scientists and other professionals who have the necessary skills to work with large volumes of information and the ability to clean and organise large datasets. This suggests that an understanding of their work would be required to manage these personnel effectively. However, the best data scientists have the ability to communicate with business leaders effectively, assisting them to overcome their challenges through utilising Big Data Analytics [23].

E. Technological Pillar

There are six barriers in the technological pillar: complexity of data; data scalability; data silos; infrastructure readiness; lack of suitable software; and poor data quality. Complexity of data is the challenge of managing data originating from a variety of sources, stored in a variety of structured and unstructured formats which may include SMS, images, videos, audio files and emails [26]. The volume of Big Data can increase at a rapid pace, Alharthi, Krotov and Bowman [26] state that most organisations do not have a plan to address this problem with many preferring to delete data rather than accommodating data growth.

Data scalability refers to the challenges of storing the large volumes of Big Data, as many organisations have to delete their data after a certain period to allow newly created data to be stored [28]. Arunachalam, Kumar and Kawalek [28] state that relational databases offer limited data scalability and therefore suggest that technologies including Hadoop, NoSQL, distributed file systems, parallel computing and Cloud Computing could be implemented to accommodate data scalability.

Data silos are isolated datasets without links to other datasets, for example data stored by individual departments of an organisation in separate information systems [24]. In a survey of 40 Thai SMEs, Noonpakdee, Phothichai and Khunkornsiri [32, p. 3] stated that: 'Different business units in SMEs use different applications and store data in separate databases which could bring about problems of duplicate data, or inaccurate reports. Some SMEs do not have database management systems'. Therefore, a challenge of adopting Big Data Analytics will likely be the integration of isolated datasets.

Infrastructure readiness refers to the development of IT infrastructure to facilitate Big Data Analytics, which may require significant investment in hardware and software, as many of the existing technologies utilised by a business are likely not to support Big Data [26]. SMEs may already have data which could be defined as Big Data but their infrastructure is inadequate to facilitate Big Data Analytics [25]. Alharthi, Krotov and Bowman [26] state that Big Data infrastructure can be designed using low-cost commodity hardware, however the servers and storage systems are connected via ethernet or fibre networks, therefore the network infrastructure must support the high throughput and bandwidth associated with the large volumes of data transmitted between servers.

Lack of suitable software is one of the issues with identifying suitable Big Data Analytics solutions for SMEs. Coleman et al. [30] state that Big Data Analytics is divided into two parts: potentially useful but complicated solutions which require data scientists; and simpler but less-effective solutions. Additionally, solutions which provide both an intuitive user interface and strong analytics capability are rare [30]. Bianchini and Michalkova [6] state that although solutions are becoming more affordable, the products currently available are not specifically designed or priced for SMEs.

Poor data quality issues refer to the suitability of the data. As Big Data Analytics is utilised for decision making, it is essential that the data is fit for purpose to provide decision makers with confidence [27]. Sejahtera et al. [24] state that data quality issues may include: incorrect formatting, lack of unique identifiers, duplication, missing data, miss classification, poor data quality control at the point of input. Lee [27, p. 301] highlights that: 'as data are more unstructured and collected from a wider array of sources, the quality of data tends to decline'.

Table IV below shows the final list of barriers to SMEs adopting Big Data Analytics, categorised into the five pillars.

V. Conclusion

Big Data Analytics has been more widely adopted by large organisations, but SMEs can also benefit from the use of Big Data Analytics. However, although SMEs are a key part of the UK economy, accounting for over 90% of businesses and 60% of employment, Big Data Analytics has not yet been widely adopted by SMEs. SMEs have demonstrated a willingness to adopt new technology for operational purposes as shown by the adoption of Cloud Computing and e-commerce but have been slower to adopt analytical technologies such as those required by Business Intelligence (structured data) and Big Data Analytics. The greater complexity of Big Data which may require specialist skillsets and infrastructure to maximise its potential, means that SMEs are likely to find the adoption of Big Data Analytics even more challenging. There is a strong business case for SMEs to investigate Big Data Analytics to identify how it can be utilised to achieve a competitive advantage particularly in post Covid-19 environment. Further work will be undertaken both quantitively and qualitatively with practitioners involved in SMEs to help validate and evaluate the barriers identified and the corresponding pillars selected and this will be subject of future publications.

TABLE IV. Revised list of SME barriers to Big Data Analytics Adoption categorised into five pillars

Business	Environmental	Human	Organisational	Technological
Financial barriers	Ethical concerns in data use	Lack of in-house data analytics expertise	Change management	Complexity of data
Lack of business cases	Inability to assess and address digital risks	Shortage of consultancy services	Cultural barriers	Data scalability
	Regulatory issues		Insufficient volumes of data to be analysed	Data silos
	The lack of common standards		Lack of managerial awareness and skills	Infrastructure readiness
			Lack of top management support	Lack of suitable software
			Management of technology	Poor data quality
			Talent management	

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