Government Office for Science

Foresight

Understanding the impact of emerging technologies on the freight sector

Future of Mobility: Evidence Review

Foresight, Government Office for Science

Understanding the impact of emerging technologies on the freight sector

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February 2019

This review has been commissioned as part of the UK government's Foresight Future of Mobility project. The views expressed are those of the author and do not represent those of any government or organisation.

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This report has an information cut-off date of May 2018.

Executive summary

The freight transport and logistics (FTL) sector is experiencing a new wave of digital technologies, which is bringing dramatic advances in what computers can do, and has the potential to be the dominant mode of monitoring, understanding, analysing, evaluating and planning sustainable freight logistics.

To understand the opportunities offered by these emerging technologies in managing supply chains and freight flows, an extensive review was conducted, using a wide range of academic and practical resources. This led to a high-level synthesis of digitalisation in freight and logistics, as well as a detailed exploration of major technological trends. Seven emerging technologies were identified, which are likely to have a major impact on the UK freight sector:

1. Cloud computing
2. Internet of Things (IoT)
3. Social media networks
4. Artificial intelligence (AI)
5. Big data analytics
6. Immersive technologies
7. Distributed ledger technology (DLT).

These technologies were found to enable smart and digitalised applications and to support various practical, sector-specific activities, such as digital rail, smart motorways and smart port programmes. These and similar digital applications have great potential to enhance the sustainability of transport in respect of its physical, environmental, economic and social dimensions. However, with the exception of cloud computing and IoT, the review found limited empirical evidence to demonstrate the value created by these technologies for freight, mainly due to their early stage of deployment in this sector.

In terms of penetration, cloud computing and social media networks enjoy wider adoption than the others, with IoT closely following. Both cloud computing and IoT have become the backbone of FTL systems. Big data analytics and AI, though less mature, have received substantial private and public investment recently. The penetration of immersive technologies in the freight sector is currently the least developed and still in its infancy. Empirical evidence suggests that AI, IoT, big data analytics and immersive technologies (particularly blockchain) are likely to have the greatest impact in the future, given their potential for driving better decisions, increasing productivity, streamlining supply chains and intermodal processes, and developing new, data-driven business models and concepts. The review also identified challenges to the further adoption of these emerging technologies, including the cost of implementation, lack of expertise and talent, security, privacy and legal concerns, and an absence of standards.

This report hypothesises a future ideal freight ecosystem, and discusses the roles of its key actors. It looks at the required structural changes that will influence the freight sector, and identifies other technologies that intersect with trends in this area, covering globalisation, domestic and cross-border e-commerce, the sharing economy, 3-D printing and industry 4.0.

In conclusion, the report puts forward the following policy recommendations in order to enable the UK government to lead globally on digital freight exploitation and to develop the UK's international competitiveness:

- investing and facilitating innovation:
    - invest in research and development through various funding schemes, such as research councils, Innovate UK and Digital Catapult
    - develop specific interventions in innovation weak spots
    - consider various mechanisms to accelerate adoption, such as public–private collaboration and mandated use of proven technologies;
- addressing skills shortages and workforce retraining;
- making cybersecurity a top priority; and
- developing standards.

Contents

Introduction

The transport sector is currently experiencing a paradigm shift, with coinciding transitions in the fields of energy use, digital technologies and behavioural change. These changes have started to affect the way in which the freight transport and logistics (FTL) sector operates. This shift must be fully understood to harness the opportunities and benefits it brings, while mitigating potential disruptions.

This report addresses the opportunities that emerging digital technologies present in managing supply chains and freight flows. This includes looking forward to the implications of decisions that need to be made today. An extensive review was conducted for this report, using a wide range of academic and practical resources and evidence (see Section 5). Key findings are presented, and recommendations suggested to enable the UK government to lead globally on digital freight exploitation and to develop the UK's international competitiveness.

The report is structured as follows. Following this Introduction, Section 2 provides an overview of major technological advances in the freight sector. It starts with a brief examination of the historical development of digitalisation in freight and then articulates a high-level characterisation of the current system. Please note that this report refers to the current state of the technological landscape in the freight sector. While some technologies outlined may advance to a more mature stage in the future, others may not ultimately see a wide uptake. All nonetheless have the potential to disrupt the current status quo. Section 3 explores the potential economic, social and environmental implications of the emerging technologies described in Section 2. It envisages the desired shape and nature of our future ecosystem in the next two decades. Section 4 concludes the report and concentrates on policy implications. It proposes four key areas where the government should invest its efforts in order to improve the UK's global competitiveness.

2. A review of emerging technologies in Freight Transport and Logistics (FTL)

The evolution of digital developments

To understand the current digital transition in FTL, it is necessary to take a holistic view and to examine the evolutionary path of digitalisation in the past few decades. Digitalisation in FTL dates back to the 1960s. Most information and communication technology (ICT) systems were standalone applications, dealing with only one function of FTL within an organisation, such as transport scheduling or invoicing. The development of electronic data interchange (EDI) was a breakthrough that facilitated interorganisational data transactions. When the internet was commercialised in the late 1990s, a plethora of internet-enabled ICT systems were deployed in the freight sector, greatly enhancing its efficiency through the automation and optimisation of freight transport operations. Table 1 shows an observable trend of digitalisation, from unconnected applications to connected systems and networks, emphasising the data storage principle of 'a single source of truth (that is, to always source a particular piece of information from one place), modular design and on-demand use.

Table 1: Historical developments of digitalisation in FTL, 1960s–2020 and beyond

Evolutionary stages	1960s	1970s	1980s	1990s	2000s	2010s	2020+
Typical FTL systems	Accounts receivable, inventory management and control	Transport planning application, MRPI	TMS, WMS, MRPII	ERP, DSS CRM	ERPII, internet-based ELM or e-logistics network	Internet-based community systems, mobile apps	Industry-wide IoT platform, private and public blockchain, smart supply chain systems
Emergent IT trends	Standalone applications	Siloed functional applications	Applications portfolios	Integrated systems, web 1.0	Service-oriented architecture and web-based services	Multi-scale ecologies, cloud computing, web 2.0, mobile and social networking	Blockchain, Web 3.0, IoT, AI, immersive technology
Integration focus	Functional	Functional	Functional	Internal end-to-end integration in a company	External integration, extended value chain	Multi-enterprise, collaborative value network	Distributed network integration and automation
Business applications	Transaction automation	Business function automation	Desktop and workgroup automation	Enterprise-wide automation	Industrial system automation	Cross-industry automation, loosely coupled flexible configuration	Insight-driven systems leveraging big data analytics, visualisation techniques and machine intelligence
Supporting computer technology	Mainframe computers	Mini-computers	Personal computers and local area networks	Enterprise-wide computing	Internet and web platform	Internet and web, mobile platforms	Blockchain enabled distributed network, 5G communication network, quantum computing
Abbreviations used: MRPI=Material Requirements Planning; MRPII = Manufacturing Requirements Planning; ERP = Enterprise Resource Planning; ERPII = Extended ERP; TMS = Transport Management System; WMS= Warehouse Management System; DSS = Decision Support System; CRM = Customer Relationship Management; ELM = Electronic Logistics Marketplace							

Source: Adapted from Wang & Pettit, 2016

Following Merali et al. (2012), we can summarise the key characteristics of ICT developments in the FTL sector as follows:

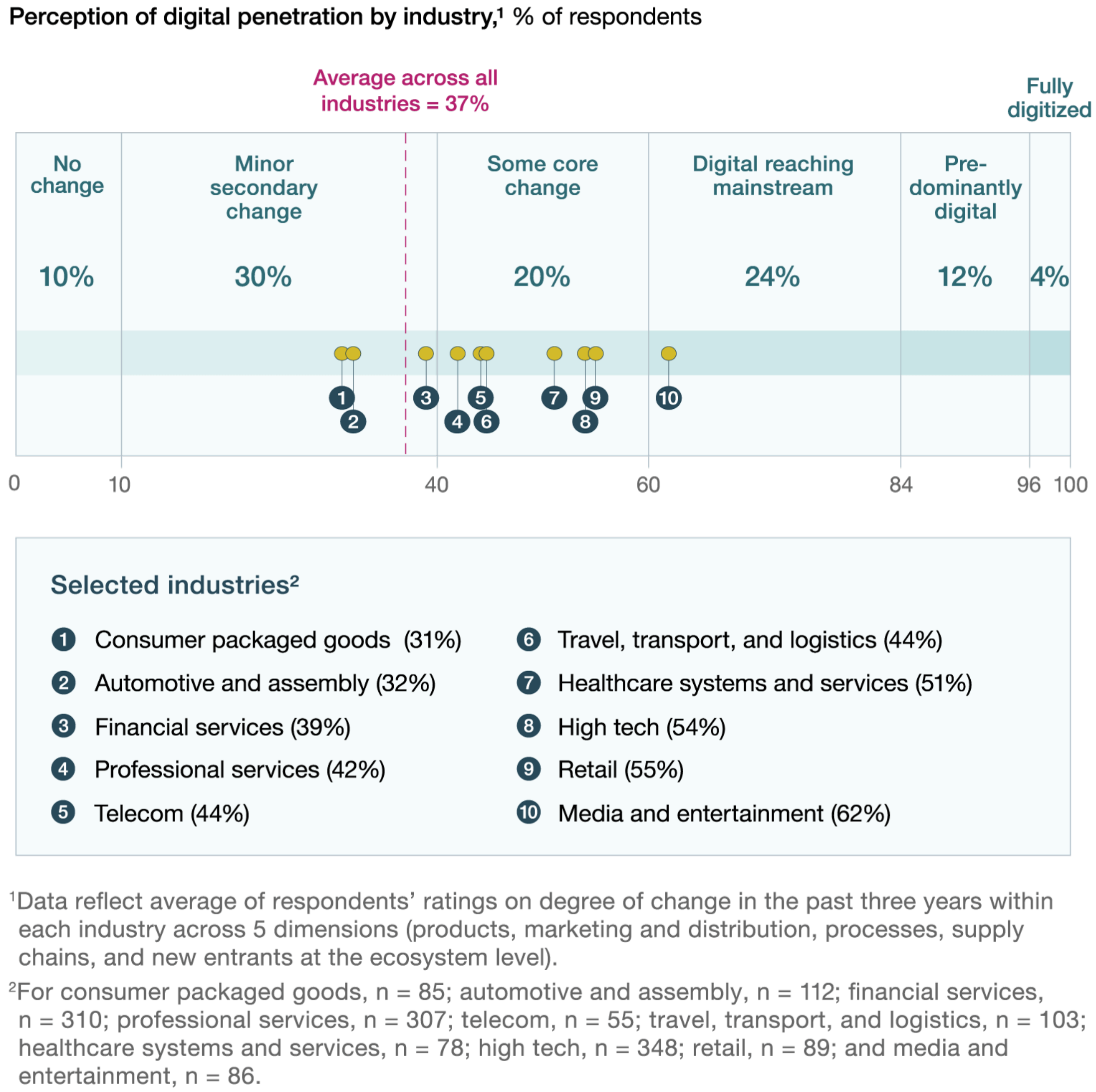
- connectivity (between people, applications and devices);
- capacity for distributed storage and data processing;
- reach and range of information transmission; and
- rate (speed and volume) of information transmission.

If we take a snapshot of current digital FTL systems, it is notable that many heterogeneous systems co-exist and interact with each other. These interactions may be asymmetric, with varying degrees of interconnectivity and interdependence, contingent on prevalent conditions and local sensibilities. On the one hand, recent technical advances have made digital connectivity more flexible and less costly, while on the other, these advances create complexities and difficulties for organisations regarding the form that electronic links and relationships should take between them and their various supply-chain partners. This open, asymmetric nature of complex systems introduces more uncertainties, unpredictability and turbulence to the FTL sector, making effective deployment of ICT systems problematic and challenging. Typical issues include fragmented development of different software applications and standards, interoperability issues between different systems, lack of technical expertise, and the time and cost of deployment. Increasing ethical, security, environmental and legal issues further compound the complexity of these emerging technologies. Therefore, the ability to manage a portfolio of ICT systems is a necessary strategic capability for users and providers of freight and logistics services, and the key to assuring the effective flow of information and materials in supply chains. These challenges call for effective policy intervention and infrastructure development to ensure the FTL sector remains competitive in the global marketplace.

We can also observe that digitalisation penetrates all sectors, although to varying degrees, and to consider why variations occur between sectors. Not surprisingly, sectors such as retail, media and entertainment take the lead in digitalisation, while travel, logistics and transport play catch-up. This perceived penetration differs among different transport modes and nodes,[1] and between large and small- or medium-sized enterprises (SMEs). For instance, the UK's road freight sector has many SME logistics service providers, many of which face financial and technical constraints in adopting digitalisation. Rail freight, by contrast, is dominated by only a few large operators, and operates in a highly regulated and centrally managed infrastructure. The UK's air freight moves high-value and time-sensitive products, most of which have international destinations. However, despite electronic air waybill penetration of over 50%, most of the global air trade still relies on paper-based processes. A shipment can generate up to 30 paper documents and many tracking processes still depend on human intervention (Noll, 2017). Priorities and efforts concentrating on digitalisation therefore differ according to sector, and the nature of the transport and logistics provider under discussion. Figure 1 shows the perception of digital penetration in the FTL sector compared with that in other sectors.

[1] The term 'transport node' is used to refer to the complex combination of processes, physical locations, technical devices and management systems that make up an integrated transport system. For example, a transport node includes the process of transportation (air, road, sea etc.), places such as warehouses, railway stations, ports and highways, and systems of control and management for transportation flows.

Figure 1: Perception of digital penetration of FTL sector compared with other sectors



Source: Bughin et al., 2017a

Characteristics of the current system

This section summarises emerging technological trends based on evidence from a wide range of resources, including both general and sector-specific reports on emerging technologies, and evidence from academic research, practice and literature. See Appendix A for further details of sources used.

Cloud computing

The deployment of cloud computing has become mainstream. Using a network of remote servers hosted on the internet to store, manage and process data, cloud computing allows third parties to host ICT systems on behalf of their customers. Its flexibility and ease enable not only large companies but also SMEs to use the system, significantly reducing entry barriers for SMEs and fuelling new business models pioneered by technology service providers (TSPs). For example, the use of telematics and GPS for tractor- and trailer-tracking is well established in road freight. On-demand models promoted by TSPs allow haulage companies to lease rather than buy tracking devices, representing a significant saving on fixed assets. From infrastructure as a service (IaaS) and software as a service (SaaS) to platform as a service (PaaS), cloud computing offers flexible technology for the freight sector, allowing flexible scaling-up of models. This can be expected to increase with the enhanced connectivity offered by full fibre and 5G.

Pervasive computing

As computing power increases, and smart devices become smaller, more affordable and capable, people and devices become more connected than ever before. Such ubiquitous connectivity and network services enable real-time visibility across supply chains, which is critical for dealing with rising uncertainty and complexity in freight transport, especially in multimodal environments (Harris et al., 2015). A key enabler for such technological development is pervasive computing (Satyanarayanan, 2001).

The most prevalent forms of pervasive computing includes ubiquitous computing,[2] ambient intelligence,[3] sentient computing[4] and the Internet of Things (IoT). While each form has a slightly different focus, in practice, all of these augment everyday objects with microelectronic sensors and actuators, and wireless communication capabilities (Bibri & Krogstie, 2017). Hence, they become ‘smart’ objects. They ‘know’ where they are, which other things are in the locality (context awareness) and what happened to them in the past (Friedewald & Raabe, 2011).

Big data

These smart objects provide huge volumes of data, both structured and unstructured,[5] thus providing new insights for experimentation, predictive planning, maintenance and delivery. This ‘big data’ collected from various sensors improves life-cycle asset management – an important factor in asset-heavy sectors such as FTL. Big data is so valuable that it constitutes a new asset class for the freight sector. As a result, big data analytics have become more prominent, resulting in transformative, strategic-level impact. For example, dynamic transport planning and timetabling using real-time data from smart objects would allow simultaneous cargo- and carrier-tracking, so maximising transport infrastructure capacity.

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[2] Ubiquitous computing is a concept in software engineering and computer science where computing is made to appear everywhere and anywhere. Computers will function invisibly and unobtrusively in the background, and make everyday objects smart by enabling them to communicate with each other, interact with people and their objects, and explore their environment, thus helping people to carry out activities or tasks whenever and wherever needed.
[3] Ambient intelligence (AmI) refers to the presence of a digital environment that is sensitive, adaptive and responsive to the presence of people. This is the term preferred by the European Union.
[4] Sentient computing denotes the use of sensing devices to observe and monitor and computing devices to perceive (recognise and interpret) and react to the physical environment.
[5] Unstructured data is a generic label for any data that is not contained in a database or has a clear structure. Textual data (such as email messages or social media dialogues) or non-textual (data such as images or video files) are typical examples.

Artificial intelligence

As intelligent algorithms become more sophisticated and computing power grows significantly, machines start to gain human-like cognition, which enables them to, for instance, drive trucks, airplanes or trains. This led to the concept of artificial intelligence (AI). Robotics and autonomous vehicles (AVs), computer vision, language, virtual agents and machine learning are the key developments of this technology (Bughin et al., 2017). High-tech and financial services are the leading sectors for AI deployment. The automotive and assembly sectors were some of the first to implement advanced robotics for manufacturing and developing self-driving cars. Retailers rely on AI-powered robots to run their warehouses, automatically ordering stock when inventories run low, and even running unmanned stores. With smartphone penetration, retailers must develop omni-channel sales strategies, which AI can help optimise, update and tailor to each shopper in real time. The FTL sector is less aggressive in AI investment and exploitation, due to the relatively slow pace of digital transformation in the industry. The FTL's adoption of AI could be accelerated by the demands of its customers, retailers and manufacturers.

Middle-layer software applications convert massive amounts of data into something intelligent that brings strategic benefits for organisations. At the application level, there are two emerging trends: those of centralisation and decentralisation.

Centralisation

Supply-chain and logistics processes are increasingly handled by platform-based online systems that harvest data from different sources to ensure 'one version of truth'. This trend occurs across all four transport modes, as evidenced by the concepts of single-window systems, electronic logistics marketplaces, port community systems and air-cargo ecosystems. Reasons for using deploying platform-based systems include a desire to simplify the complexities of day-to-day transactions among cargo stakeholders, which include customs, forwarders, shippers, shipping lines, terminal operators, inspection agencies, hauliers and railway operators. Online platforms bring all such stakeholders together, allowing them to communicate with each other seamlessly and enabling the re-use of data so that it only need be entered on the system once. Prior to this technological development, communications were bilateral and mostly paper-based. The same information often had to be submitted multiple times to various parties, leading to errors, duplications and inefficiencies. Similarly, single-window systems can save resources, reduce human error and speed up trade flows. For instance, by launching a single-window system for cross-border trade, China largely reduced the time to clear imported goods at customs from seven days to 19.4 hours, and reduced the time for exports to 1.2 hours (gov.cn, 2017).

Decentralisation

The decentralisation trend reflects the rising deployment of IoT in supply chains and digital twins and distributed ledger technology (DLT) (sometimes known as blockchain). One major pitfall of a centralised system is with all the data is stored in one place, there is a higher level of vulnerability. If a system is hacked or there is some technical malfunction, the whole system may be brought to a halt. Decentralised systems such as DLT offer an alternative way to manage data. A DLT is a shared ledger of records or transactions, open to inspection by every participant, but not subject to any form of central control. Although it is still in its infancy, many believe that DLT is a 'game changer' for its potential impact on supply-chain structures, relationship configurations and cash flows (Casey & Wong 2017; Wang et al., 2018). For the FTL sector, the value of DLT lies in its extended visibility and traceability, a reduction in the number of intermediaries in the supply chain, and benefits for data management and secure, smart contracts (Wang et al., 2018). For example, in the shipping sector, various pilot schemes use DLT to facilitate information-sharing among stakeholders, shipment booking and real-time container monitoring.

The technology landscape is evolving at an unprecedented pace. While not all emerging technologies will alter the freight sector, some have the potential to disrupt the status quo. The following section discusses the seven key trends identified as having the greatest potential to affect the UK's freight systems.

Key technology trends

Seven technology trends are likely to have a major impact on the UK freight sector. Some are more mature, such as cloud computing and IoT, while others, such as DLT and immersive technology, are in their infancy. Together they represent major opportunities and disruptions to the sector.

Trend no. 1: Cloud computing

	Cloud computing is the delivery of computer services – especially data storage, hosting, processing and analytics – through the internet. For organisations, cloud computing removes the need to buy in hardware and software, or to run on-site data centres with all the attendant ongoing costs. Organisations are typically charged for cloud-computing services based on their usage. This can free them up to focus on their core business strategies.

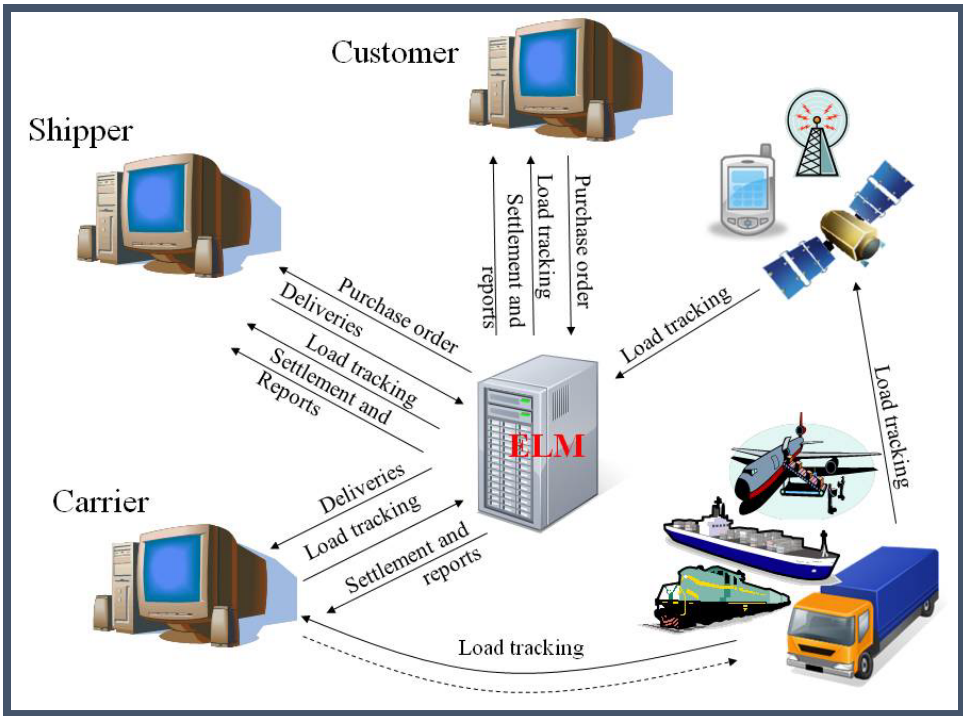
A typical example of cloud computing in a multimodal transport environment is a cloud-based electronic logistics marketplace (ELM). ELMs are web-based ICT systems that link shippers, carriers and customers for transport service spot trading (i.e., for immediate settlement, known as 'open ELM'), or for information-sharing and long-term collaboration (termed 'closed ELM') (Wang et al., 2007).

The traditional method of communication between shippers and carriers, and between shippers and their customers, is bilateral and fragmented. For example, if the customer wanted to track down a consignment, they would have to contact the shipper, who would then contact the relevant carrier for an update. In a global transport and multimodal environment, the process would be even more complicated. The lack of visibility and communication delays often lead to a fire-fighting approach when something goes wrong.

Figure 2 illustrates how a closed ELM can manage the order-fulfilment process and speed up communications across the whole supply chain. The process starts with the customer generating an order in the cloud-based ELM and the order is automatically transferred to the shipper. Following this, transport planning and execution take place between the shipper and carrier. While the goods are in transit, the system provides constant updates on the status of the consignment to all parties involved. A closed ELM could either be hosted in-house or by a third-party TSP. One of the major advantages of a cloud-based

ELM is that it provides centralised management with all the data relating to a specific consignment, meaning that any change can be simultaneously communicated to all parties involved. This increased visibility gives companies more control over the supply chain. The system also facilitates financial settlements and performance reviews of total delivery cost and on-time delivery. By changing the structure of communications between shippers and carriers, an ELM integrates various modes of transport into an interconnected, streamlined supply chain, resulting in cost reductions and improvements to customer service (Wang et al., 2007).

Figure 2: A cloud-based ELM



Source: Wang et al., 2010

Cloud computing, compared with other technologies, is probably the most established technology in freight. The most frequently mentioned impact of cloud computing is affordability, and specifically cost savings in terms of capital expenditure, labour costs and power and cooling costs (Leimbach et al., 2014). For SMEs, cloud computing offers a high level of security when there is a lack of in-house expertise. Cloud computing also give organisations the flexibility to scale up or down quickly, allowing businesses to experiment and launch new services and products much more quickly. This may lead to the emergence of new start-ups and potentially new job opportunities.

One area of concern is the potential loss of jobs when organisations outsource their ICT provision and move instead to a cloud-based system. However, a recent extensive review of cloud computing by Leimbach et al. (2014) did not find evidence of 'both large job growth with cloud computing providers and large job reductions in company IT departments'. Other common concerns include downtime, support for legacy systems, security breaches and privacy. Finally, we should note that cloud computing is not suitable for everyone. For example, it is not suitable for services that require high speed, such as systems to control machines on the shop floor.

Trend no. 2: Internet of Things

	The Internet of Things (IoT) is the term used for networks of physical devices, including vehicles, home appliances and traffic-control systems, that are embedded with low-cost sensors and actuators for data collection, monitoring, decision-making and process optimisation. IoT interacts and operates without conscious human intervention.

In road transport, the concept of Intelligent Transport Systems (ITS) has long been established, albeit not specifically designed for freight. For example, motorways are embedded with sensors that monitor vehicle movements, plan for maintenance and manage congestion. In rail freight, modern signalling technologies track information on real-time train movement, which is transmitted to the control office for traffic management. Seaports are playing catch-up with large transport and logistics players and have started developing insight-driven solutions and IoT applications (Berns et al., 2017).

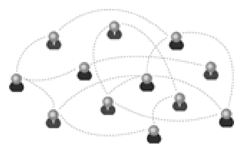
Currently IoT's main deployment in FTL lies in product- and service tracking and monitoring, for example inventory management and control in the supply chain, real-time routing, dynamic vehicle scheduling, management of trailers, containers and other heavy assets, and shipment tracking. Railroad tracks, AVs and flight navigation can derive further value from IoT (Manyika et al., 2015). In sectors actively exploring the use of IoT, radio frequency identification (RFID) is the most widely used smart object in supply chains. RFID tags contain embedded microchips that allow freight operators to track individual assets and containers and to determine the temperature and humidity of frozen or liquid goods or a vehicle's mechanical condition (Sarac et al., 2010; Wang & Potter, 2007). One example of innovative IoT use is that of the German carmaker, Daimler, which launched the car2go service, which uses IoT functionality to monitor and manage cars remotely, allowing customers to use shared cars as required. This represents a radical change in Daimler's business model, transforming it from a car manufacturer to a mobility service provider. Retailers are at the frontier of IoT adoption as well. Sensors already automatically check out customers and restock the retail inventory post-purchase. RFID tags track inventory throughout the store, shelf sensors ensure the inventory is on display, and mobile payments reduce checkout queues.

The concept of the digital twin is closely related to the IoT. A digital twin is a virtual doppelganger of a real-world thing, or a complex ecosystem of connected things, such as an AV in the middle of rush-hour traffic. Engineers can analyse how a vehicle performs not just in its physical environment, but over its entire life cycle. Digital twins are particularly valuable in the telecommunications, transport and construction sectors, where the management of an asset's life cycle is critical to its correct functioning. IoT, simulation software, and machine learning and predictive analytics systems are three emerging technologies that enable digital twins. Although many people still *interface* with digital technologies via keyboards, screens etc., interfaces will not be needed in the future. Instead, we will *interact* with them, thanks to the instantaneous two-way communication enabled by IoT.

While there is overall positivity about IoT (Borgia, 2014), a recent survey by the Economist Intelligence Unit (EIU, 2017) reveals that IoT has not progressed as fast as expected. The survey indicates that major barriers relate to the high cost of IoT infrastructure, security and privacy concerns, and a lack of senior management knowledge and commitment. Another barrier is the limited range of connectivity offerings in the marketplace, which are restricted to unlicensed forms (e.g., wi-fi), low-power wide area networks (LPWANs, e.g., SigFox and LoRa), and cellular (currently 4G) and extra-terrestrial (satellite or other microwave technology) networks. If an organisation chooses one connectivity option and another becomes dominant, its IoT devices, applications and solutions are at risk of becoming obsolete. Cellular 5G networks might eventually become a universal solution for IoT connectivity, but will not be widely available until at least 2023 (Alsen et al., 2017; EU, 2016). This implies that organisations may need to find a middle-ground solution until 5G is available, and hence this compromised adoption may cause less optimal results and reluctance to invest. A typical example is the case of Network Rail's deployment of the European Train Control System (ETCS, a digital signalling system). ETCS can be deployed at levels 1, 2 or 3. Level 3 means that all trackside signals and train detection equipment is replaced by equipment on board the train. However, level 3 is currently not available, so level 2 is deployed instead. According to the House of Commons Transport Committee's report (2016), level 2 requires expensive trackside equipment, whereas level 3 does not require the same degree of capital investment.

Intensive use of IoT devices such as RFID may invade consumers' privacy. Organisations that provide individuals with RFID tags that remain functional and could be read at a later stage should have a general policy of transparency about the existence of the tags, any associated privacy risks and measures to mitigate these risks. The rising number of IoT devices also increases security risks because many connected devices have less secure software and are vulnerable to malware. A large number of these devices run the Linux operating system, which means that they can be reprogrammed once access has been acquired, and therefore could be used to deliver distributed denial of service (DDOS) attacks (Winchcomb et al., 2017).[6] To make things worse, many devices are manufactured without the capability to upgrade or patch device software, exposing their further vulnerabilities.

Trend no. 3: Social media networks

	In the business context, social media networks are web-based platforms upon which social interactions occur within an organisation or externally with its stakeholders. Increasingly, social networks are used for multiple purposes, including knowledge management, financial transactions, customer service, order taking, tracking and project management.

The best-known social networks are popular online social media platforms such as Facebook, Twitter and LinkedIn. However, social networks have evolved beyond just connecting people and facilitating online socialising and communication. Organisations from private, public and third sectors have attempted to reap more benefits than just engaging with their target stakeholders. For instance, some businesses use social media and web clickstream analysis to enhance customer survey data in order to better understand the 'voice of the customer' (Trainor et al., 2014). Others use large social

[6] A DDOS attack is an attack in which multiple compromised computer systems attack a target, such as a server, website or other network resource, and cause a denial of service for users of the targeted resource. The flood of incoming messages, connection requests or malformed packets to the target system forces it to slow down or even crash and shut down, thereby denying service to legitimate users or systems.

networks to understand the dynamics of influence, including mobile sensor-based data for enhanced spatial–temporal behaviour analysis (Abbasi et al., 2016; Aral & Walker, 2012). The world's largest container shipping company, Maersk Line, is one of the pioneers in the FTL sector in this area, using different social media platforms to engage its key stakeholders and the public at large, and generating significant social capital for the business in the process (Katona & Sarvary, 2014).

Social networks provide SMEs with a cost-effective way to market to, and connect and communicate with, their customers. They also play an active role in humanitarian logistics. For example, during the Haitian earthquake in 2010, social media facilitated faster decision-making and emergency responses, as well as effective acquisition, sharing, use and maintenance of knowledge (Yates & Paquette, 2011). Although 72% of companies use social media in some way, few do so to its full potential (Chui et al., 2012). In the FTL sector, the deployment of social media is on the rise. According to a survey of 117 logistics experts (INFORM, 2015), 36% use social networking services in supply chain management, 21% in their purchasing departments and 20% in transport logistics. Road haulage companies actively use social media for recruitment, branding and marketing (Potter et al., 2017). The survey suggests that the greatest benefits of social networking may lie in courier, express and package delivery services. Another survey conducted by McKinsey Global Institute (2017) found that the use of social media tools has grown in operations processes, especially in procurement, supply-chain management and after-sales services.

Although the financial benefits are difficult to quantify, the effective use of social networks can improve the public's perception of a company's presence. This is essential for the logistics industry, as it often operates in a business to business (B2B) environment and rarely attracts mainstream consumer awareness. Social networks help speed up information- and knowledge-sharing, strengthening bonds with customers and improving communications with suppliers and other partners. Social media platforms are increasingly used for instant order-taking and tracking, financial transactions and customer service. In China, Weixin/WeChat has become the most popular social app, with over 938 million users worldwide (Tencent.com 2017), offering comprehensive services including free text and multimedia messages, video calls and photo- and file-sharing as well as a 'one-stop shop' e-commerce (EC) service. The EC service allows users to buy items or services via the app, process financial payments and access after-sale services. Users can buy plane tickets, book a doctor's appointment or order a taxi. Weixin/WeChat has evolved into a connector and open platform across industries, connecting users with one another, with smart devices and with business services. The impact of these innovations on traditional supply chains and logistics activities is far-reaching. New terms such as 'social commerce' and 'social economy' highlight the increasing popularity and opportunities brought about by social networks (Chui et al., 2012; Stephen & Toubia, 2010).

In addition to their external use, social networks are equally powerful if deployed effectively within an organisation. When used internally, social media applications are often referred to as enterprise social media or organisational social network systems. These are designed to bring visibility to informal relationships in an organisation, support cross-functional collaboration, identify relationships between individuals and provide a medium for informal interactions unbounded by hierarchical constraints (Karoui et al., 2015). Although still in its infancy, enterprise social media has demonstrated the following benefits (Beck et al., 2014; Karoui et al., 2015; Leonardi et al., 2013):

- improved employee productivity through the intensification of interactions;
- facilitation of new internal relationships;
- generation of collective intelligence and knowledge exchange;
- facilitation of collaborative work; and
- fostering of innovation.

The combined use (both internally and externally) of social networks, according to Bughin and Chui (2013), could lead to the creation of a fully 'networked company' that supports strategic organisational functionality, as well as effective external engagement with customers, suppliers and other stakeholders. Freight operators and service providers could use social networks internally for knowledge-sharing, problem-solving and project management. Equally, they could deploy such networks externally for tasks such as taking orders and providing instantaneous, personalised customer service. If this personalised service is further augmented by AI, we may see a radical change in how freight service providers interact with their customers. Social networks are also a popular choice for freight service providers to engage with future employees by humanising their brand image and displaying a corporate culture.

To exploit the full potential of social networks, the FTL sector needs to tackle its current lack of expertise in the use of social media. It needs to develop a cohesive strategic approach to managing multiple social platforms without risk of reputational damage. The power and importance of social media in this area are well known: Greenpeace's social media campaign against Nestlé for using unsustainable palm oil is just one example (Harrild, 2010). The campaign led to Nestlé changing its policy and severing contracts with Sinar Mas, a major palm-oil producer and supplier that had been heavily criticised by Greenpeace for deforestation and peatland clearance in Indonesia. However, privacy, trust and proper handling of personal information are critical aspects of social networks. There could be potential conflicts between users' intentions to share personal information and the way information is used by the organisations that host such platforms.

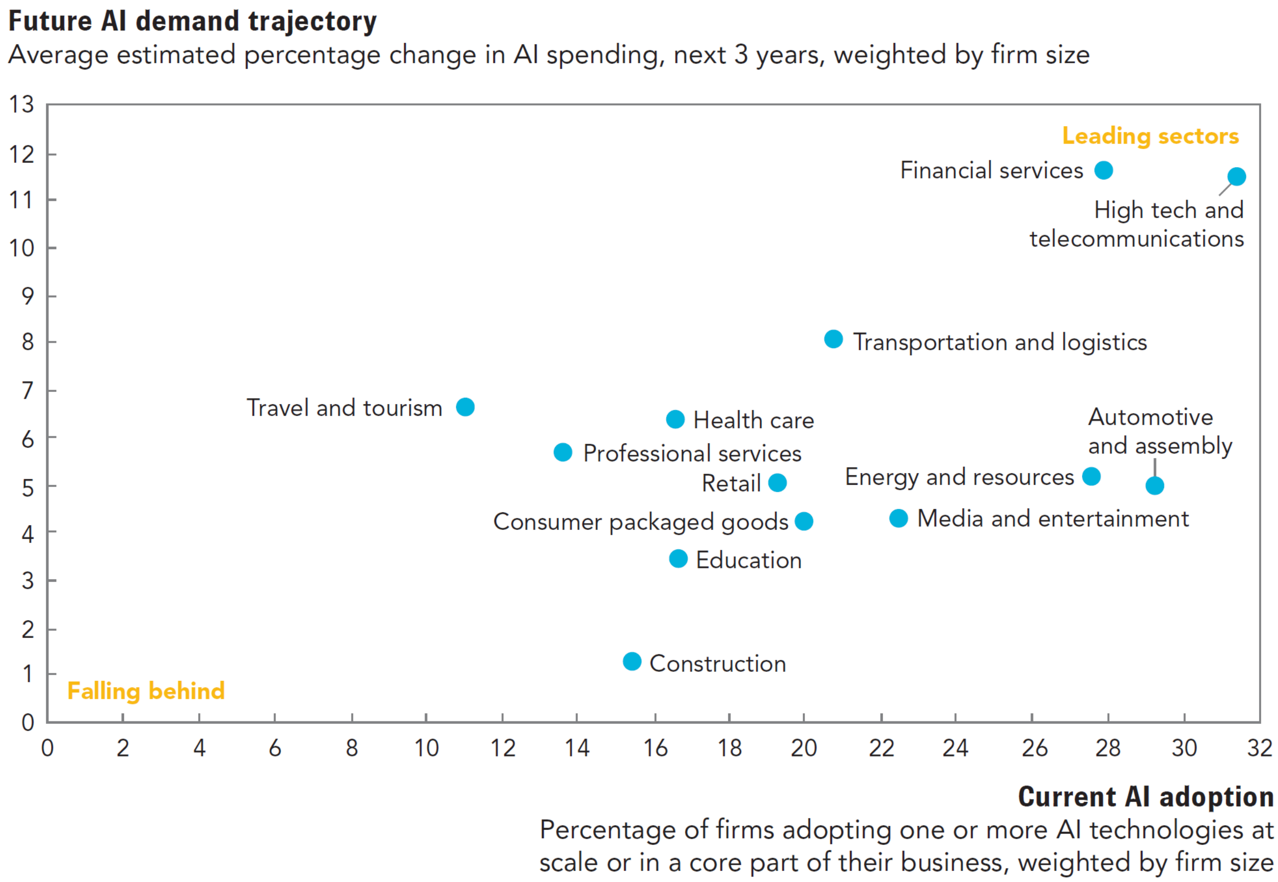
Trend no. 4: Artificial intelligence

	Artificial intelligence (AI) is a set of related technologies that make machines do things that would require intelligence if done by humans. AI systems have the ability to keep improving their performance without humans having to explain exactly how to accomplish all the tasks undertaken.

AI enables a machine to learn from experience, arrive at conclusions, appear to understand complex content, participate in natural-language dialogues with people, enhance human cognitive performance and replace people for non-routine tasks (Andrews, 2017). Its current applications include healthcare diagnoses, banking, education, predictive maintenance, legal applications, customer service, automated data centres, autonomous vehicles and smart homes. After six decades of development, AI is approaching its tipping point and is poised to contribute to widespread commercial applications (Thomas & Liang, 2016).

Recent automation and AI developments have accelerated, triggered by sophisticated machine-learning algorithms based on neural networks, increased computing capacity and the emergence of big data. A landmark of AI development was the victory by DeepMind's AlphaGo computer program over a human champion (Lee Sedol) in the complex board game, Go, in 2016. A familiar example of AI is the voice-activated AI personal assistant (such as Amazon's Alexa and Apple's Siri). To date, most of the investment in AI consists of internal R&D spending by large, cash-rich, digital-native companies such as Amazon, Baidu and Google, while much of AI adoption outside the tech sector is at an early, experimental stage (Bughin et al., 2017). The US and China have taken the lead in strategic national plans for investment in AI development (Barton et al., 2017). South Korea and the UK have similar strategic plans, recognising AI's significant social and economic impact (Hall & Pesenti, 2017).

Figure 3: Sectors leading in AI adoption



Source: McKinsey Global Institute, 2017

Figure 3 shows current and predicted AI adoption by sector. Clearly, manufacturing and financial services are leading the use of AI. For manufacturers, AI is deployed to automate assembly lines, predict sales of maintenance service, and optimise route and fleet allocation for logistics activities. Transportation and logistics demonstrate a reasonable scale of AI adoption. This reflects the substantial progress made towards truck automation and platooning in recent years.[7]

Truck automation requires AI to process the vast amounts of data collected by a vehicle's sensors. For example, truck automation requires spatial recognition and an understanding of the vehicle's immediate environment as well as its exact location. Limited self-driving automation requires the ability to anticipate the behaviour of other vehicles, pedestrians and animals while simultaneously considering the movement of the vehicle. Although there have been significant developments in AI, these capabilities are not fully developed (Eastwood, 2017).

Another area of AI application is in robotics and warehouse automation. Articulated robots have been seen in warehouses assembling pallet loads from trailers and containers for years. The use of next-generation robotics for online e-commerce (EC) order fulfilment is one of the new areas for further diffusion. EC orders are usually small, often requiring only one or two items to be picked up at a time. Current industrial practice of order-picking is largely manual, hence large EC fulfilment centres tend to employ hundreds of pickers and packers in order to achieve their delivery targets, particularly during peak seasons such as Christmas and Black Friday. Many have an ambitious target of 15 minutes from click to ship, which is only achievable with the use of robots (Cooper, 2018).

Some believe that finding labour will be more challenging in the future. This makes a more compelling case for the adoption of robotic picking. Large logistics companies such as DHL have piloted the use of autonomous robotics cobots for picking.[8] Amazon is also a pioneer in robotics. It spent $775 million in 2013 to buy a start-up, Kiva, which builds mobile robots. These robots can pick up a shelf of goods and bring the entire shelf to the picker who can stay in one spot to assemble the order, eliminating the need for excessive walking between aisles in a warehouse. This concept is known as 'goods-to-picker' and in some cases has led to 50% saving in warehouse picking labour (DHL, 2016).

Further to the challenge of stock picking, is the challenge of inventory management. Some companies are using autonomous drones for inventory management (Jackson, 2017). They save considerable time and money, when compared to human equivalents of checking the stock in large warehouses.

In addition to warehouse automation and inventory management, the use of AI in retailing could anticipate demand trends, optimise product assortment and pricing, personalise promotions, offer immediate assistance with virtual agents, automate in-store checkouts and complete last-mile delivery by drones. In the context of virtual assistants, the concept of 'conversational technology' emerges, powered by rich visual interfaces and AI (Mimoun & Poncin, 2015). Apart from its application in education and smart homes, conversational technology has emerged in customer service (via messaging apps), allowing a continuous customer–brand conversation. These app-based, AI-driven conversations enable the

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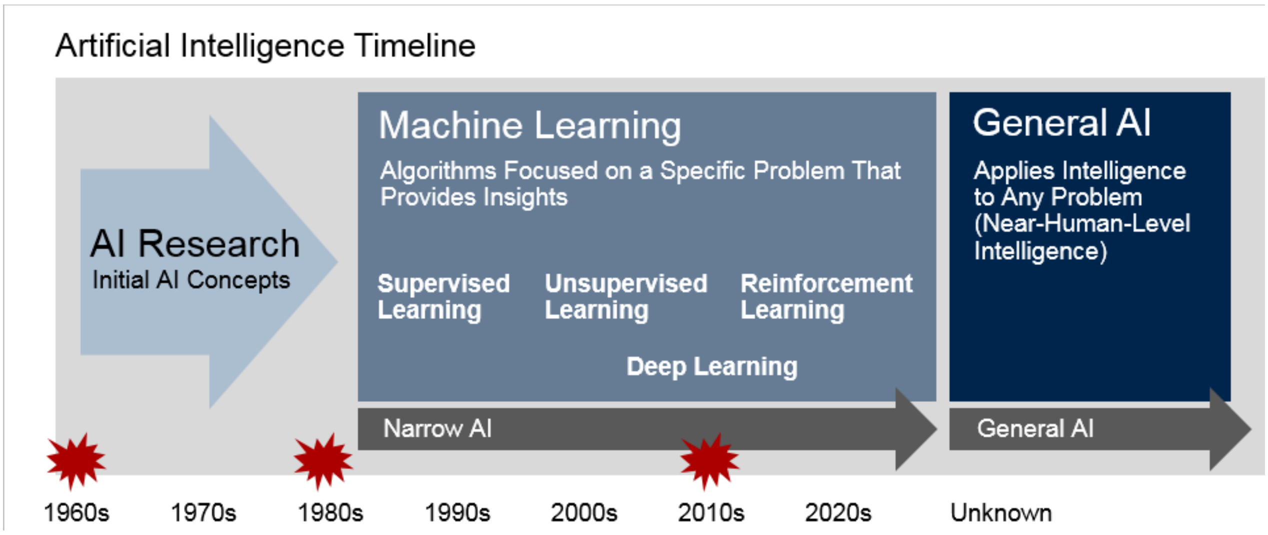
[7] 'Platooning' refers to several freight vehicles that are travelling autonomously in convoy and in communication with each other (ITF, 2017a). It involves a lead truck whose human driver navigates traffic, with several trailing vehicles automatically undertaking the steering and braking required to maintain a safe (mostly fixed) distance from the vehicle in front. This concept is currently being trialled in Europe, and has the potential to increase the volume of freight traffic (Highways England, 2017).

[8] 'Cobots' are collaborative robots that work side-by-side with human employees, supporting repetitive and physically demanding tasks in logistics.

brand to zoom in on what customers need, regardless of how they say it, based on an understanding of context (BenMark & Venkatachari, 2016). Such conversational technologies may diffuse into logistic areas such as warehouse picking and vehicle loading, where operators receive specific guidance and advice in real time to complete their tasks. It may be useful for simulated training and learning as well.

Figure 4: AI timeline



Source: Gartner, 2017

AI can be categorised into 'narrow' AI and 'general' AI (Cearley et al., 2017; Gartner, 2017) (figure 4). While general AI seeks to perform any intellectual task that a human can do, 'narrow' AI consists of highly scoped machine-learning solutions that target a specific task, such as understanding language or driving a vehicle in a controlled environment (Bughin et al., 2017; Cearley et al., 2017). The algorithms chosen are optimised for that specific task. All the real-world examples of AI in use or development are examples of narrow AI.

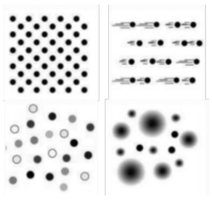
Table 2 broadly categorises AI applications and offers examples of their use in FTL.

Table 2: Categories of AI applications in FTL

Purpose	Use scenarios in FTL	Areas of development
Process information	Text analytics, natural-language processing, speech recognition and semantics technology Examples: • real-time voice translation so that the international staff of a regional warehouse can understand each other; and • image-processing to autoselect the proper box size for packing specific items for shipment.	Computer vision and language
Act on Information	Robotic process automation that mimics the activity of a human being in carrying out a task within a process. Examples: • automated specific repetitive human tasks within logistics processes such as warehouse order picking; • autonomous forklifts and other self-piloted equipment in warehouse operations (potentially including drones); and • truck platooning and delivery by drone.	Robotics and autonomous vehicles
Interact on information	Computer programs that can converse with humans Examples: • virtual personal assistants to help employees do their jobs more effectively; and • virtual customer assistants take customer orders, and provide customers with fast and accurate resolutions.	Virtual agents
Learn from information	Learn from data without relying on rule-based programming. Automatically detect patterns in data, and then use the uncovered patterns to predict future data, or perform other kinds of decision-making under uncertainty. Act as an enabler to other applications such as robotics and speech recognition. Typical applications in the supply chain include predictive analytics, demand forecasting, scheduling and resource planning, operational efficiency and customer insight. Examples: • recognise recurring scenarios and trends, and link these to specific customers and orders • anticipate the content of an order, and pre-pick and pack before orders are placed; • in last-mile delivery, monitor each step of the process to deliver dynamic route-planning tailored to each recipient's daily routine; • integrate IoT, to predict when equipment or vehicles need repair and maintenance; and • track individual shipments, create automatic alerts when exceptions happen (e.g. when the temperature of a container or trailer is compromised), then propose (or take) corrective measures.	Machine learning (with a subfield of deep learning)

Although automation and AI will improve productivity and economic growth, they are not without concerns, such as the potential effects on employment. According to the latest McKinsey report, 60% of occupations have at least 30% of work activities that could be automated (Manyika et al., 2017). Even so, even with automation, the demand for work and workers could increase as economies grow, partly fuelled by productivity growth enabled by technological progress. During this transition, the workforce needs to be reskilled to exploit AI, rather than compete with it, and governments with ambitious AI strategies will need to join the global competition to attract AI talent and investment (Bughin et al., 2017). Autonomous robots powered by AI may also threaten human identity, uniqueness, safety and resources, and hence progress is required on the ethical, legal and regulatory challenges that could potentially inhibit AI (Złotowski et al., 2017). Companies also need to adapt to different ways of working, whether in integrating AI or on-demand workers (World Economic Forum, 2016).

Trend no. 5: Big data analytics

	Big data is a term applied to datasets whose size or type is beyond the ability of traditional relational databases to capture, manage or process with low latency. It has one or more of the following characteristics: high volume, high velocity or high variety. A new characteristic, ‘veracity’, was added to describe the uncertainty of data. Big data comes from sensors, devices, video and audio input, networks, log files, transactional applications and web and social media, and is normally generated in real time and on a large scale.

AI, social media and IoT are driving data complexity and generating new forms and sources of data. This has led to an explosion in the amount of data captured and has subsequently challenged the information-processing capabilities of traditional database software tools (Wang & Pettit, 2016). Within this context, the concept of ‘big data’ emerged. Its four key attributes were defined by IBM (Zikopoulos, deRoos et al., 2013):

- volume: scale of data;
- velocity: the rate at which data arrives at the enterprise and the time that it takes the enterprise to process and understand that data;
- variety: different forms of data; and
- veracity: uncertainty of data, i.e. the quality or trustworthiness of the data.

Big data often contains both structured and unstructured data.[9] Insights gained through advanced predictive analytics, particularly by analysing unstructured data, are the new frontier for innovation and productivity (McAfee & Brynjolfsson, 2012; Waller & Fawcett, 2013). Achieving this advantage, however, demands both technological and cultural change, merging traditional and new analytical techniques to uncover new insights while embedding evidence-based decision-making into core processes that drive business (Pringle et al., 2015). Big data analytics use advanced techniques against large (in

[9] Proprietary information is structured data, lodged in databases, analysed in reports and presented in all familiar formats such as spreadsheets. Unstructured data would be, for example, social conversations conducted on social media.

terabytes to zettabytes) and diverse datasets that include structured, semi-structured and unstructured data.

According to Waller and Fawcett (2013), the potential applications of big data in logistics could manifest in the following areas: forecasting, inventory management, transportation management and human resources (Table 3).

Table 3: Potential applications of big data in logistics

User	Forecasting	Inventory management	Transportation management	Human resources
Carrier	Time of delivery, factoring in weather, driver characteristics, time of day and date	Real-time capacity availability	Optimal routing, considering weather, traffic congestion and driver characteristics	Reduction in driver turnover, driver assignment, using sentiment data analysis
Manufacturer	Early response to extremely negative or positive customer sentiment	Reduction in shrink, efficient/quick consumer response, vendor-managed inventory	Improved notification of delivery time and availability, surveillance data for improved yard management	More effective monitoring of productivity, medical sensors for safety of labour in factories
Retailer	Customer sentiment data and use of mobile devices in stores	Improvement in perpetual inventory system accuracy	Local traffic congestion and weather linked to store	Reduction in labour due to reduction in misplaced inventory

Source: Waller & Fawcett, 2013

For road transport, big data may enable preventive maintenance and better utilisation of vehicles. For example, GPS-based telematics tracking by most haulage companies means that data from in-vehicle sensors, related to engine performance and driving behaviours, is constantly collected (Wang & Potter, 2007). Such data is then used for preventive maintenance of the vehicle and driver training. Real-time vehicle-tracking data would allow companies to dynamically schedule and (re)route vehicles, with journey times offered, backed up with live traffic data for accurate predictions. This enables companies to provide demanded delivery-on-time performance. In the fashion sector, attempts to utilise real-time customer return data to divert one customer’s returns to fulfil another customer’s order no long requires warehouse processing (Cullinane et al., 2017).

In shipping, new tools are available, combining GPS data on the current position of vessels with the latest machine-learning analysis techniques. Such tools can estimate the deviation between the current and scheduled position of a ship and provide better estimated time of arrivals for any port on its route. Real-time information on equipment performance and smart maintenance of onboard systems are increasingly embedded in daily operations (Tu et al., 2016).

Rail transport operators, by collecting massive amounts of data from sensor-equipped train cars, can not only forecast potential breakdowns, but also institute overhaul, replace or upgrade schedules (O'Brien, 2016). Data analytics advise optimal maintenance plans, thereby avoiding the disruptions that a mechanical failure could cause.

Big data is of great value to airline operators for asset maintenance and repair. Data collected from sensors can help assess the breaking points of materials in complex vehicles for part-failure analysis. Aircraft maintenance staff can look for part fatigue and failure at the material level. Big data generates greater insights and foresights, thus allowing transportation companies to implement strategies for predicting operational failures.

For infrastructure operators such as Highways England and Network Rail, big data analytics reveals traffic hotspots using fixed and mobile sensors, and can be used to evaluate the benefits gained from new investment. It also promotes asset maintenance management, and enables real-time traffic data to inform commuters' decisions. Big data may also inform sustainable infrastructure planning by providing better estimates of future trends in transport demands through enhanced data linkage and modelling (House of Parliament, 2014).

One major challenge is how to make sense of big data. Logistics practitioners and researchers are often are overwhelmed by big data. Traditional decision-support systems are not capable of managing and analysing unstructured data. Consequently, to gain the most out of big data, advanced predictive analytics tools are needed. Data mining, case-based reasoning, exploratory data analysis, business intelligence and machine learning could help firms mine unstructured data (Tan, Zhan et al., 2015). Companies such as IBM are exploring new techniques, such as cognitive computing systems, which claim to help human experts make better decisions by penetrating the complexities of big data (Zikopoulos, deRoos et al., 2015). Several industries use Hadoop, an open-source software framework for working with various large datasets. It breaks a big dataset into smaller clusters, processing them systematically, and combining the results into smaller datasets that are easier to analyse.

Another challenge is the lack of analytical and managerial talent (Davenport & Patil, 2012). People with these skills are hard to find and in great demand. The exploration of big data also poses challenges to organisational structures, culture and leadership, and requires a new mindset for decision-making. Finally, data governance, privacy and confidentially demand clear legal structures for data-sharing. As big data extends to new domains such as predicting behaviour from online activities, it achieves greater accuracy in pinpointing individual behaviour. This has ethical implications, because such predications may undermine individuality and free will. If big data analysis is also used not only for predicting but also for manipulating future behaviours (e.g. to influence purchasing behaviour), it will lead to further social consequences (Schroeder & Cowls, 2014).

Trend no. 6: Immersive technologies

	Immersive technologies blur the boundary between the physical and the digital (or simulated) world to create a sense of immersion. Related terms include virtual reality (VR), augmented reality (AR) and mixed reality (MR).

Immersive technologies provide a stimulating, multimedia digital environment for people to experience, rather than just read, watch or listen. Given that the boundaries between products, services and environments have blurred, immersive technologies are increasingly applied in practice. Currently, there is strong demand for immersive technologies from industries in the creative economy – specifically gaming, live events, video entertainment and retail (Hall & Takahashi, 2017) – but wider applications are found in the manufacturing and maintenance, tourism, healthcare, education, transport and construction industries (Liu & Wang, 2017; Neumann et al., 1998; Papagiannakis et al., 2008). For example, in construction, Contain UK applied augmented reality (AR) to its construction project (Custom House station in east London), allowing its customer Crossrail to view the planned construction works in a 3-D image overlaid onto a view of the real site with an iPad (Cousins, 2014).

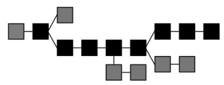
There are subtle differences between VR, AR and MR (see Appendix B). AR is by far the most deployed term both academically and in practice. There are limited studies on the impact of immersive technologies specifically in the FTL sector, but obvious areas of application include on-the-job training, real-time process instruction, navigation and wayfinding aids, and digital interaction with customers and partners. Cirulis and Ginters (2013) point out that AR could significantly improve some logistics operations, including order-picking in a warehouse using path-finding techniques. Integrated with existing technologies such as voice-picking, this could improve the productivity of the workforce and radically change the way employees perform tasks.

KiSoft is an example of a picking system using AR technology, which displays information regarding location through a head-mounted display (KNAPP, 2013). The purported advantages include visual, error-free picking instructions with fully automated goods and serial-number tracking, adaptable to every warehouse without any structural changes. In the retail sector, Tesco began augmented technology trials, where web cameras and mobile devices view life-size projections of products before purchase (Whiteaker, 2011). Immerseuk.org (2017) have illustrated how immersive technologies have trained ground operation crew in the aviation industry, demonstrating the value of AR for training when the real environment is potentially dangerous or noisy, or when employees are unable to experience real-life situations or learn on site. Another example is Unilever's use of collaborative robots and VR simulators to automate repetitive manual tasks and improve the safety, operation and maintenance of equipment. Its technicians use AR glasses to record and share best practice in maintenance procedures across the network (Aronow et al., 2017).

There are still technical issues associated with immersive technologies, such as heavy wearable devices whose prolonged use often results in sickness and disorientation, raising health concerns. Another barrier to its development is the limited supply of talent (Hall & Takahashi, 2017). To encourage its further diffusion, governments could actively invest in this technology and search for new forms of human–machine interface. For example, in

France, the government provides funding for AR and VR producers to co-produce films with traditional filmmakers.[10] Another concern is data confidentiality and privacy. In the EU and the UK, the General Data Protection Regulation (GDPR) came into effect in May 2018, and necessitate unambiguous consent for data collection. However, the potential impact of GDPR on the development of immersive technologies is not yet clear, and the future trading relationships add further uncertainties.

Trend no. 7: Distributed ledger technology (DLT)

	DLT refers to an encoded digital ledger that is stored on multiple computers of a public or private network. It comprises data records, or 'blocks'. Once these blocks are combined in a 'blockchain', they cannot be changed or deleted by a single actor, and consequently are verified and managed using automation and shared protocols.

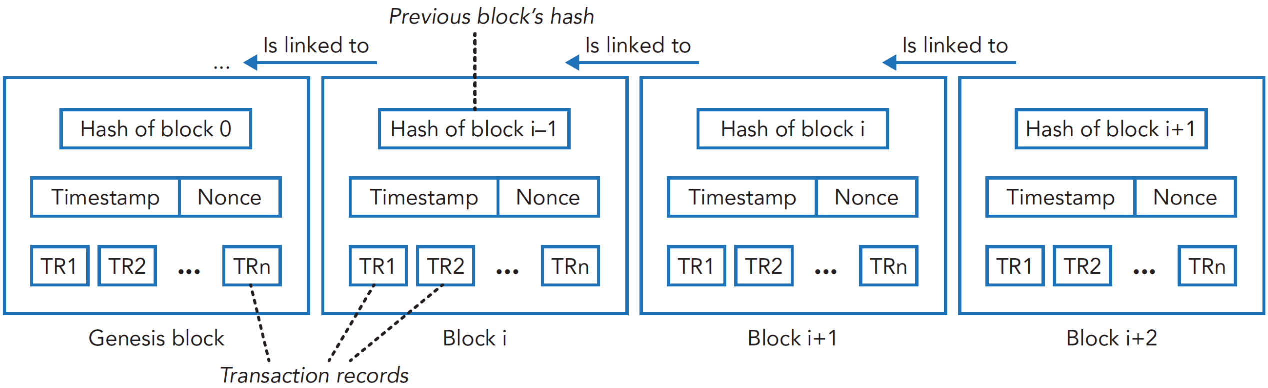
Widely considered one of the most disruptive technologies, DLT enables the creation of decentralised currencies such as Bitcoin, self-executing digital contracts ('smart contracts') and intelligent assets that can be controlled over the internet (Kshetri, 2018; Kosba et al., 2016). DLT can be perceived as another application layer that runs on top of internet protocols that enable economic transactions between relevant parties. It can also be used as a registry and inventory system for recording, tracing, monitoring and transacting assets (whether tangible, intangible or digital). From a business perspective, a blockchain is a platform whereby values are exchanged among peers without requiring any trusted third party.

First proposed by Nakamoto (2008), recent efforts to use DLT have been largely in the areas of financial transactions and distributed ledger systems (Pilkington, 2015). As noted above, DLT architecture underpins cryptocurrencies such as Bitcoin, using a shared database that updates itself in real time and can process and settle transactions in minutes using computer algorithms, with no need for third-party verification, such as those normally conducted by a bank.

However, DLT's impact goes far beyond financial transactions. Since DLT allows secure data exchanges in a distributed manner, it is beginning to affect how organisations are governed, supply-chain relationships are structured, data is shared and transactions are conducted. Integrated with IoT, DLT could create a permanent, shareable and actionable record of every moment of a product's trip through its supply chain, creating efficiencies throughout the global economy. Improved visibility also affords product traceability, authenticity and legitimacy – critical for food and luxury product supply chains. DLT is also instrumental in the value systems of the sharing economy (Huckle et al., 2016; Pazaitis et al., 2017).

[10] See www.cnc.fr/web/en/aide-aux-cinemas-du-monde

Figure 5: A standard blockchain string



Source: Yli-Huumo et al., 2016

One type of DLT is the blockchain. A blockchain is an encoded digital ledger that is stored on multiple computers of a public or private network. It comprises data records, or 'blocks'. As each transaction occurs, it is put into a block. Each block is connected to the one before and after it. Each block is added to the next in an irreversible chain and transactions are blocked together – hence 'blockchain' (Figure 5). Once these blocks are collected in a chain, they cannot be changed or deleted by a single actor, and instead are verified and managed using automation and shared protocols (Swan, 2015). This is the core innovation of blockchain.

The verification process, along with modern encryption methods, can effectively secure data on blockchain ledgers against unauthorised access or manipulation. Since it is barely possible to overwrite existing blocks in the chain (doing so would require massive amounts of computing power to access every instance), users always have access to a comprehensive audit trail of activity (Miles, 2017). As a rule of thumb, the bigger the blockchain network, the more tamper-resistant it is. The decentralised storage of information reduces the risk of single point of data access failure associated with centralised databases.

There are two main types of distributed ledgers, based on access control mechanisms, regarding who can read a ledger, submit transactions to it and participate in the consensus process. Permissioned ledgers are a viable option for the freight ecosystem (Wang et al., 2018):

- Public ledger: Every transaction is public (permissionless) and users can remain anonymous. The network typically has an incentivising mechanism to encourage more participants to join the network. Bitcoin and Ethereum are examples.

- Permissioned ledger: Participants need to obtain an invitation or permission to join. Access is controlled by a consortium of members or by a single organisation.

In practice, several piloting schemes have used DLTs in supply chains. For example, in shipping, South Korea's Hyundai Merchant Marine (HMM) announced in September 2017 that it had successfully completed its first pilot voyage using blockchain technology. During the voyage of a reefer container from South Korea's Busan Port to China's Qingdao Port, DLT was applied not only to shipment booking, but to cargo delivery. Additionally, HMM tested and reviewed the combination of DLT with IoT through real-time reefer-container monitoring and management on the vessel (HMM, 2017). In the food sector, the US hypermarket chain, Walmart, said DLT trials had helped it reduce the time it took to trace the movement of mangoes from seven days to 2.2 seconds. In the energy sector, a consortium of companies, including BP and Royal Dutch Shell, plan to develop a DLT-based digital platform for energy commodities trading that is expected to be operational by the end of 2018 (reuters.com 2017). DLT has been deployed in the diamond sector to ensure the authenticity of products (Ambler, 2017).

The level of penetration of DLT in the FTL sector is still minimal, but we see clearly an active sensemaking and exploration of DLT's potential value (Wang et al., 2018). For instance, the International Transport Forum at the Organisation for Economic Co-operation and Development (OECD) set up a partnership project to identify transport-related uses of blockchain technology and to chart what the data syntax standard would look like.[11] The shipping sector is particularly proactive in this case (Lloyd', 2017), potentially fuelled by the new regulation that requires the provision of an accurate verified gross mass (VGM) of every packed container to the terminal or carrier prior to shipment:[12]

- Singapore-based Pacific International Lines inked a memorandum of understanding with PSA International and IBM Singapore in early August 2017 to develop and test proof of concept supply-chain business network solutions, based on DLT.

- Maersk collaborated with IBM in March 2017 to use DLT to digitise paperwork related to the global supply-chain process, to improve efficiency and optimise costs.

- Port of Rotterdam authorities teamed up with the city's municipal government to introduce a field lab that develops practical applications using DLT. These included peer-to-peer energy trading, more efficient arrangements of cargo flows in logistics chains, and the application of DLT for stock financing in the port logistics sector in collaboration with Exact and ABN Amro.

As with many technological adoptions, owners of large cargo consignments or shippers may drive blockchain adoption. For example, Unilever and Sainsbury's recently started a blockchain trial to test whether blockchain technology can help unlock financial incentives that improve transparency and sustainability in supply chains (CILT UK, 2017). The freight forwarding company, Marine Transport International (UK) Limited (MTI), piloted a DLT initiative called Container Streams, which used DLT to combine data from IoT sensors and shipping systems about suppliers, shippers, ports and customs organisations on a single shared ledger (worldcargonews.com 2017).

[11] See www.itf-oecd.org/blockchain-and-beyond

[12] On 1 July 2016, new requirements to verify the gross mass of a packed container entered into force under the International Convention for the Safety of Life at Sea (SOLAS). The shipper is responsible for providing the VGM by stating it in the shipping document and submitting it to the master or his representative and to the terminal representative sufficiently in advance for use in the preparation of the ship stowage plan.

Wang et al. (2018) have identified that the value of DLT lies in the areas of:

- extended visibility and traceability;
- simplification, digitalisation and optimisation of supply-chain operations; and
- smart contracts.

DLT/blockchain is seen as being of particular value to crucial supply chains (Table 4). Findings further suggest that the use of DLT in supply chains may lead to supply-chain disintermediation and reintermediation. This means that some traditional intermediaries could be phased out of the market, making room for new intermediaries providing blockchain-related services, such as data analytics or integration.

Table 4: Supply chain areas where DLT might penetrate

Supply chain areas where DLT might penetrate	Explanation
Simplification, digitalisation and optimisation of supply-chain operations (especially in a global context)	• Help process the current heavy workload on information transfer and processing. • Help manage transactions among multiple organisations for cross-border activities. • Implementation should be specific on core supply-chain operations, such as information transfer between processes. • This will take the shortest time to develop, and is potentially the most controllable area to pilot.
Providing extended visibility and traceability to stakeholders	• The improvement of visibility for end customers will raise service level standards and value. • This is an added feature that is achieved from implementing blockchain within a community of stakeholders, and therefore is achievable as the scale of implementation is gradually increased.
Smart contracts	• Potential applications are automatic validation of shipments, automated track-and-trace and multi-agent validation for information checking. • This is more of a medium- to long-term application as it may involve wider sets of stakeholders and a greater scale, and should be developed by third-party logistics (3PL) organisations once they are comfortable with blockchain's application on a smaller scale.
Crucial supply chains/industries	• Initial implementation should be prioritised in crucial supply chains, such as luxury goods (e.g. diamonds) and key commodities (e.g. oil), or fast-moving supply chains (e.g. perishable items requiring a cold chain). • These supply chains carry greater purpose and sense of urgency in needing a reliable, automatable network of information transfer. • If successful, implementation in these supply chains will be able to raise positive examples of how blockchains can benefit the supply-chain industry.

Source: Wang et al., 2018

The evidence indicates that early implementation and piloting of DLT initiatives in FTL should be favoured. Progress may be slow and uncertain in the current period, due to low levels of confidence and lack of demonstrable financial benefits, but its impact cannot be overlooked. DLTs open up new possibilities to seamlessly manage distributed and fractional capacities and offer the possibility of customised, dynamic and sized-for-purpose transport to parties. They also allow operators to manage access rights, data and payments across a broad network of unrelated and competing service providers and platforms (ITF, 2017b). DLT could become the underlying technological structure for shared automated vehicles, financial transactions and smart-contract execution (ITF, 2017c). Some believe that DLT can improve today's supply chains and logistics sector to respond to operational inefficiencies, fraud, unethical labour practices and environmental degradation (Boucher, 2017).

There are a number of challenges facing DLT's further diffusion, such as technological immaturity, the cost of data collection and system implementation, and privacy, legal and ethical concerns. DLT development presents significant regulatory challenges. The absence of an intermediary in most or all steps of the supply chain could create uncertainty for the parties involved, especially regarding automated forms of execution and supervision of transactions. Criteria are needed to ensure the legal validity and enforceability of smart contracts under the law (Boucher, 2017). Through their distributed consensual nature, DLTs also threaten the role of intermediaries such as freight forwarders in the supply chain. If indeed freight forwarders could be eliminated, this would reshuffle the whole freight sector and create fundamental changes. It might also result in job losses in the short term, though new intermediaries offering DLT-related digital services might emerge in the longer term, creating new employment opportunities. However, this means job reskilling is critically important for the freight sector in order to achieve a smooth transition to a more digitalised freight ecosystem. Cryptocurrency and a cashless society may become inevitable in the future, despite the current volatility of cryptocurrency trading on the stock market. This will not only challenge the current supremacy of governments in managing the national and international economic system, but also radically shape the current structure of inter-organisational trade terms and cash flows.

3. The future freight digital ecosystem

As established in Section 2, the FTL sector is experiencing a new wave of digital technologies. This next wave of emerging technologies will bring dramatic advances to what computers can do and will be the dominant mode for monitoring, understanding, analysing, evaluating and planning sustainable freight logistics. These underlying technologies will enable smart applications and support various sector-specific, practical efforts in digitalisation, such as digital rail, smart motorways and smart port programmes. Smartness holds great potential to enhance the contribution of emerging technologies to transport sustainability in respect of its physical, environmental, economic and social effects.

Progress in the adoption of emerging technologies

Table 5 summarises the key technological trends discussed in Section 2. Although these technologies can be deployed individually, integrated use tends to deliver greater value and impact. For example, big data collected from IoT sensors and social media can be transmitted (possibly via DLT for IoT) to cloud-based information systems for storing and processing. Big data analytics and deep machine learning would then derive 'intelligent' insights from the data collected. Insights could then guide better decision-making and task performance.

Table 6 provides a further assessment of the UK's FTL sector's competitive position in terms of researching and deploying the identified technologies.[13] The UK is well known for its cutting-edge digital capability, particularly in financial technology ('fintech'), and is a net exporter of digital services to Europe (Bughin et al., 2016; Manyika et al., 2016). For instance, among G20 economies, the UK ranked third (following the US and France) in terms of IoT penetration.[14] Its competitiveness in terms of cloud computing and big data is equally world leading (OECD, 2017; see also Appendix C). The OECD (2017) reports further evidence that during the period 2010 to 2015, the UK was among the top 10 economies in AI patents, whilst Japan, Korea and the US accounted for over 62% of patents filed.

However, the same report also reveals that the digital maturity of the FTL sector does not look promising when compared with that of other sectors, such as telecommunications and finance, with most areas (such as investment in software) lagging behind (see Appendix D). Although the OECD data does not provide UK-specific information, it does reflect the overall low level of digitalisation of the UK freight sector. It is also worth noting that the extent to which individual technology is integrated into UK freight tends to vary. While social networks enjoy rapid deployment in countries such as China, their uptake in the UK's freight sector is relatively slow and the scope of application quite narrow. The gap may be largely due to the strong appetite for all things social in China, where about 596 million people use social media almost every day, a figure that is predicted to rise to 615.5 million in 2018, twice as many as the combined population of France, Germany, Italy, Spain and the UK (Statista, 2018). Unlike social networks, which technically are more established, DLT is still in its infancy and understandably has not received much attention from the UK freight sector, although other countries such as the Netherlands have invested aggressively in the areas of maritime shipping and port management. The low-level adoption of both social networking and DLT may inhibit the UK's global competitiveness.

The digital maturity of IoT and cloud computing, on the other hand, is much more advanced in the UK, clearly evidenced in sectors such as fast-moving consumer goods (FMCG) especially in retailing and automotive industries. Coupled with big data analytics and AI, they position the UK favourably in the global marketplace. Immersive technology has only seen sporadic deployment in the UK freight sector, mostly in warehousing, but more valid user business cases may put the UK in the fast track for adoption.

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[13] Owing to the limited availability of international benchmark data, this assessment can only provide an estimated indication of the likely competitiveness of UK's position in freight and logistics digitalisation.
[14] Level of penetration is measured by number of machine-to-machine SIM cards per inhabitant.

Table 5: Summary of the implications of emerging technologies

Emerging technologies	Level of penetration (1 barely deployed – 5 fully deployed)	Impact on future freight (1 very little impact – 5 substantial impact)	UK competitive position (estimate)	Barriers and challenges to further diffusion
Cloud computing	○○○●○	○○○●○	World leading	• Concerns of downtime, security and privacy, support for legacy system • Fear of losing control
IoT	○○●○○	○○○○●	World leading	• High cost of IoT infrastructure • Security and privacy concerns • Lack of senior management knowledge and commitment • Immature connectivity technologies • Lack of standards for data-sharing and interconnectivity
Social networks	○○○●○	○○●○○	Laggard	• Lack of expertise in how to use social networks • Potential risks and unexpected outcomes
AI	○●○○○	○○○○●	World leading	• Effect on employment and the future of work • Intrusion and threat to human identify, uniqueness, safety and resources • Ethical, legal and regulatory challenges
Big data analytics	○●○○○	○○○○●	World leading	• Needs sophisticated analytical tools • Lack of analytical and managerial data talent • Data governance, privacy and security concerns
Immersive technologies	●○○○○	○○●○○	Fast follower	• Wearable devices not user friendly • Health concerns from prolonged wearing • Limited supply of talent Data confidentiality and privacy
DLT	●○○○○	○○○○●	Laggard	• Technological immaturity • Cost of data collection and system implementation • Security, privacy, legal and ethical concerns • Limited supply of talent

Economic and environmental implications

In terms of the level of penetration, cloud computing and social networks enjoy wider adoption than the five key digital trends, with IoT closely following. Both cloud computing and IoT have become the backbone of FTL systems. Big data analytics and AI have received substantial private and public investment. The penetration of immersive technologies and DLT in the FTL sector is still in its early stages. Although the impact of none of these technologies is negligible, empirical evidence, albeit limited, suggests that AI, IoT, big data analytics and DLT are likely to have the most impact in the future, given their potential for driving better decisions, lifting productivity, streamlining supply chains and intermodal processes, and developing new, data-driven business models and concepts.

Those operational improvements also lead to environmental benefits. For example, full digitalisation and DLT-enabled smart contracts will significantly reduce the mountainous amounts of paper documents typically used for FTL. Reduced journey times and optimised deliveries via dynamic scheduling lead to fewer trucks on the road and lower CO_2 emissions and traffic congestion. Better utilised assets may allow less use of energy. Academic research also found that ICT solutions have a direct positive impact on reducing CO_2 emissions in road freight (Wang et al., 2015). Environmental benefits, however, are less observable due to the immature status of some of the technologies and limited practical implementation. It is difficult to pinpoint whether such emerging technologies could lead to a modal shift (e.g. from road/air to rail). Furthermore, those technologies, although a key enabler of many strategies to mitigate environmental damage, could be a significant source of energy consumption themselves, given the computing power they need.

Employment and skills implications

While individuals in the UK will benefit greatly from digitisation as consumers, for workers, the impact is potentially mixed. Nonetheless, there is no doubt that digital technologies will transform FTL practices and reshuffle the skills inventory we need.

On one hand, low-skilled jobs or mundane and dangerous tasks will be displaced by increasing digitalisation, specifically automation and AI-enabled robotics. For example, machines already exceed human performance in collecting and processing data. Frey et al. (2017) predict that most workers in transportation and logistics occupations, together with the bulk of office and administrative support workers, are at risk due to increasing computerisation and automation. Even people with jobs that are not easily replaced by automation need to update their digital skills. All employees must embark on a lifelong learning journey to adapt to the ongoing digital revolution.

On the other hand, the development and deployment of emerging technologies create demand for new jobs. For instance, there is a great shortage of big-data analysts, data developers, data engineers, machine-learning experts, cybersecurity experts and user-experience designers. Digital tools, platforms and new ways of working also offer many opportunities. Technology raises productivity and will boost demand and create jobs outside the technology-producing sector. In the short term, there may be a decline in employment in some areas, but overall, new industries and occupations will absorb workers displaced by technology.

During the period of transition, sustained investment is needed to support job creation, new training and educational models to enable individuals to learn new skills, ease worker transition and support collaboration between the public and private sectors. Transition in the automotive age is a challenging time for all sectors and it may be more difficult for freight, given the historical negative image of the sector among the public and young people, an ageing workforce and the shortage of key skills in maritime shipping, aviation, rail and road (FTA, 2017).

Future outlook

The future freight ecosystem

The ultimate goal of freight is the delivery of anything, anytime and anywhere. We can envisage that our future digital systems for freight will be an integral part of a fully autonomous, end-to-end supply-chain ecosystem, where physical products' digital twins are managed in synchronisation with real-time movement and where integrated mobility is achieved via the seamless use of rail, road, air, water and even pipeline transport. Goods, data, cash and talent will flow smoothly worldwide and border crossing will no longer create bottlenecks. At various nodes of a supply chain, such as warehouses, ports and airports, we will increasingly see humans working alongside robots for the effective movement of goods. Social networks will be utilised for both instantaneous internal and external communication and collaboration. Warehouse inventories will be monitored by robots (potentially including drones). Products will be delivered by robots, autonomous vehicles or drones for the last leg of their journey, with minimal human intervention. High value or time critical items such as specimens or blood may be flown by drone between medical sites.

In the next two decades, we will see more heterogeneous computable components, including IoT devices spread across diverse networks that connect through middleware, dedicated IoT networks or cloud computing. Numerous IoT devices will broadcast the state of both the carriers of the cargo as well as the cargo itself, offering complete real-time visibility of any consignment.

Web-based digital platforms (either centralised or distributed powered by DLT, or both) will orchestrate and coordinate various computational entries in physical and virtual spaces into an integrative freight system. These platforms will harvest various streams of big data, and help organisations navigate their supply-chain journeys, both physically and digitally. Data-centric decisions will be augmented via advanced big data analytics, machine-learning algorithms and context-aware computing.

The access and effective use of the massive data repositories hold great potential to develop advanced and sophisticated models of vehicle mobility patterns, to understand and assess the relationship between organisational and collective mobility patterns and the environmental and socio-economic performance of freight transport sustainability. This allows simulation and prediction methods to determine patterns and models to guide and direct the operational functioning, planning and design of sustainable transport infrastructures (Bibri & Krogstie, 2017).

As our transport infrastructure becomes increasingly intelligent and digitalised, all devices and assets will be connected and actively broadcast their current state and alert us when they need maintenance or replacement. Our workforce in freight will be empowered by insights gained from AI and big data analytics, with support from immersive technologies and digital assistance to guide and augment human awareness.

Key actors

The UK's freight sector operates and competes in a global economy, and consists of a number of active players such as infrastructure owners, port and rail terminal operators, shippers, shipping lines, carriers, technology service providers, freight forwarders, legislative agencies, government authorities and trade associations. To make the ideal future a reality, a collaborative effort by is essential for digital transformation. The entire supply chain will need a strong IT underpinning to enable further digitalisation, new transparency and continuous big-data flows. Private companies must assess how emerging technologies may transform their businesses and prioritise initiatives to bring the greatest value. They will need to develop a sufficient knowledge-base for successful technological deployment.

For infrastructure operators and owners, they need to ensure both their digital and physical infrastructures are robust enough to cope with future needs such as those required by smart motorways for autonomous driving. For technology service providers, they need to collaborate on standards, protocols and platforms to ensure their interoperability. For government authorities, they need an adaptive, test-and-learn regulatory approach to keep up with rapidly developing technologies, as well as strategic plans to encourage innovation and acquire and develop talent.

Professional bodies play an essential role in advising policy development, providing training and promoting best practice. For example, in maritime shipping, the amendments to the Standards of Training, Certification and Watchkeeping for Seafarers (STCW) convention came into effect in 2013 and included new requirements for training in electronic charts and information systems. Employees need to prepare for the digital revolution by updating their digital skills and developing new capabilities.

Intersecting technologies and structural changes

To prepare for the digital transition, structural changes that influence the FTL sector and other technologies that may intersect with trends in this area need to be identified. They are discussed briefly as follows:

- *Globalisation.* On a global scale, new trade corridors between Asia and Africa, South America and within Asia will change the dynamics of the global supply chain, and influence the structural flows and demand for freight. In the UK, the first container freight train from China arrived in London in January 2017, signalling the far-reaching effect of China's 'One Belt—One Road' corridor initiative (dbcargo.com 2017). The growing pervasiveness of internet connectivity and the spread of digital technologies have accelerated the global flow of data, goods, services, finance and people. Global production systems are experiencing paradigm changes with manufacturers such as GE and Apple switching from offshoring to reshoring or nearshoring. The UK ranks sixth in McKinsey's latest country connectedness index (2014) (see Appendix E). Although it is highly connected across all flows, it lags in goods flows. Although the result is understandable given UK's reputation in knowledge-intensive flows and its position as a global financial hub, it does highlight that there is room for further improvement.

- *Domestic e-commerce.* Owing to e-commerce, urban freight flows are changing, with a significant growth in household deliveries. E-commerce customers tend to buy from multiple online platforms with small but more frequent orders, and expect to receive their items quickly (with increasing demand for same-day delivery) and with free returns. Last-mile delivery is thus more critical. These demands challenge traditional logistics practices and reduce the economy of scale they have gained over the years. In serving the consumer market, full truckloads will decrease while less-than truckloads increase. Driven by consumer preferences, autonomous vehicles, including drones, are likely to dominate the last mile in the future.

- *Cross-border e-commerce (CBEC).* Until recently, business to consumer (B2C) transactions have been mainly domestic. Owing to rapid developments in digital and logistics connectivity, and rising consumer demand, CBEC has seen explosive growth. Total global cross-border online retail reached $1.6 trillion in 2014 and is expected to continue to grow steadily at 14% a year, reaching $3.4 trillion by 2020 (Ali Research and Accenture, 2015). For instance, in the UK, 25% of adults purchased goods online from other EU countries in 2015, compared with only 12% in 2008 (UK Office for National Statistics, 2016). CBEC represents a new market opportunity for freight but is not without its challenges, as orders are much smaller, more diverse and often feature higher ordering frequency. This poses a new challenge for border agencies too. Border-crossing and custom clearance are often perceived as a bottleneck for CBEC. Digital initiatives discussed in Section 2 (e.g. platform-based single window systems) may help address this issue and speed up the process. For the UK the nature of future trading relationships may change the complexities and demands on border crossing.

- *Sharing economy.* The concept of a sharing economy has found its way into the FTL sector with Airbnb-type online platforms connecting supply and demand to warehousing spaces. Soon we may also see the 'uberisation'[15] of workforce management that many truck or train drivers, airline pilots, seafarers and others work on short-term contracts or freelance roles instead of permanent contracts. Uberisation for last-mile delivery allows businesses to cope with erratic delivery demands while remaining cost-effective in operations. Shutl, a same-day delivery service company, is one example of this concept in practice. It serves as a 'speed-dating agency', matching an individual's delivery requirement to the optimum courier in real time.

- *3-D printing/additive manufacturing*. This role is expanding from rapid prototype creation to an alternative way of producing finished products in a plant or at home. Offering design freedom, it promotes innovation in both products and business models (Rayna & Striukova, 2016). 3-D manufacturing has subsequent supply-chain and logistics implications. For instance, it reduces the need for long-distance shipment of goods and moves production closer to where demand is. Meanwhile, it

[15] Uberisation is a new and evolving variation of commercial transaction, whereby agents exchange under-utilised capacity of existing assets or human resources (typically through an online platform) with low transaction costs.

may generate greater demand for small cargo or parcel deliveries across shorter distances. As manufacturing becomes more decentralised, digital connectivity becomes more critical to ensure an agile response to demand.

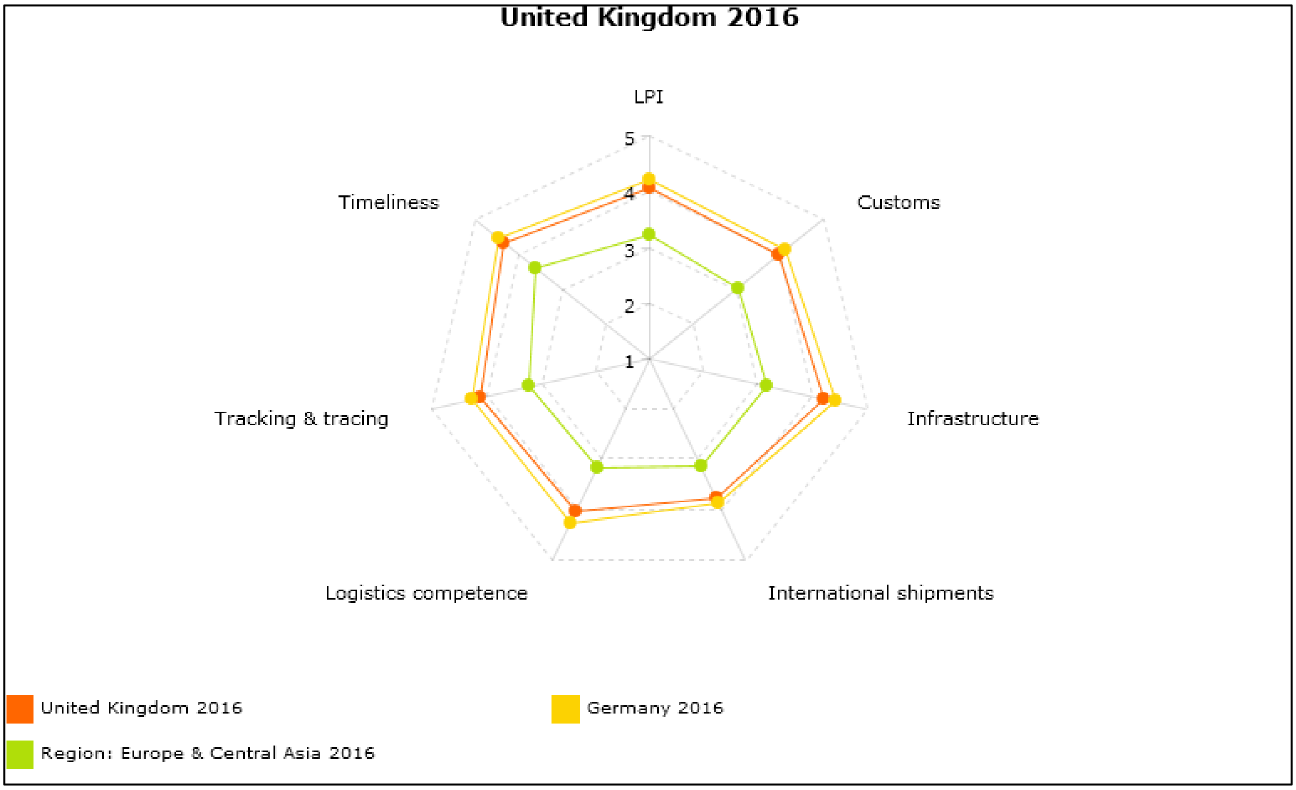
- *Industry 4.0.*[16] Industry 4.0 is the digitalisation of the manufacturing sector, driven by similar forces as those for freight digitalisation, such as big data, advanced analytics and AR. As such, cross-fertilisation and integration with FTL are inevitable, given that both manufacturing and freight are integral parts of supply chains. Although much of the positive hype has been built up, implementation has been slow. Structural changes in manufacturing will largely influence how freight operates, and therefore any digitalisation efforts in manufacturing will directly impact freight and should be observed closely.

[16] Industry 4.0 means this is the fourth major upheaval in modern manufacturing, following the lean revolution of the 1970s, the outsourcing phenomenon of the 1990s, and the automation that took off in the 2000s (Baur & Wee, 2015).

4. Policy implications

Logistics performance captures how well a country can move goods. The UK is a global leader in logistics, consistently ranked in the top 10 in the World Bank's Logistics Performance Index (LPI) (World Bank, 2016; see also Appendix F). Figure 6 compares the UK's performance in six categories against Germany (ranked first) and its region and income group. For the definition of six key dimensions, please refer to Appendix F.

Figure 6: The UK's logistics performance against its region and Germany (top performer)



Source: World Bank, 2016

Note: Scale 1 = 'very low' performance; 5 = 'very high' performance

To continue improving the UK's global competitiveness, the government needs bold ambition regarding freight digitalisation. Just as the Digital Built Britain strategy was launched in 2016 for construction, a digitalisation strategy is needed for freight and transport. The government needs a test-and-learn regulatory approach to mitigate the uncertainty of emerging technologies. The UK government also needs to make workforce transition and job creation urgent priorities. The following recommendations are suggested, based on this review.

Investing in and facilitating innovation

Invest in research and development

Given the embryonic nature of emerging technologies, the value that a particular technology will bring to the freight sector is often unclear. The government should create test beds to try out applications. The research councils, Innovate UK, Digital Catapult and the Hartree Centre, alongside other enabling organisations, are the conduit for the development and implementation of identified technologies. Technology solutions that pave the way for integrated, seamless inter-modal mobility for freight and its sustainability should be at the centre of investment.

SMEs often face more barriers to technological adoption. Knowledge and technology transfer programmes (such as the Knowledge Transfer Partnership schemes supported by Innovate UK) will help to build and improve their digital capability, which is critical to competing in the global marketplace. Pilot applications and best practice will demonstrate clear benefits and lead to increased adoption among SMEs.

Investment in IT infrastructure is of paramount importance to connectivity and mobility to facilitate global flows of data. The UK has been at the frontier of capturing the potential of digitalisation and the government is on track to maintain its global leadership. The Department for Digital, Culture, Media and Sport issued an update to the 5G strategy for the UK in December 2017, outlining several policy areas to support 5G's development and the pathway to a 5G future including measures to improve connectivity on railways and motorways (gov.uk 2017).

Develop specific intervention in innovation 'weak spots'

Specific interventions are needed in subsectors where innovation is slow. For instance, innovation in the rail freight industry has historically been slower than in other transport modes due to a highly regulated environment and the long lifetime of rail assets (Girardet et al., 2014; OECD, 2016). Currently, the European Rail Traffic Management System, a modern railway-signalling technology, is being deployed by Network Rail. However, though suited to passenger lines, it does not accommodate well the specific needs of rail freight (House of Commons Transport Committee, 2016).

Consider various mechanisms to accelerate adoption

In terms of technology-specific investment, AI, IoT and autonomous vehicles are high on the government's agenda, while DLT technology has not received same attention. The governments of the Netherlands, South Korea and Singapore have actively explored DLT via public–private collaboration, which is an effective mechanism for technological developments. For example, in 2017, the Antwerp Port Authority and Federal Participation and Investment Company (FPIM) jointly acquired a stake in NxtPort, the digital data platform for the port community. The contribution by these new partners (Port Authority 75%, FPIM 25%) in capital and a subordinated loan totalled €5.25 million (portofantwerp.com 2017).

The mandated use of technology is another way to support digital diffusion. The government mandated the use of Building Information Modelling (BIM) to maturity level 2 in all centrally publicly procured projects by April 2016. This accelerated BIM adoption enhanced the sector's digital capability, as well as producing substantial cost savings and efficiency gains (Wang et al., 2017). Such practice in construction could be replicated in freight to scale up the deployment of proven technologies.

A word of caution, however: even though their net effect in the longer term was ultimately positive, emerging technologies could cause job losses and displacement in the short term. Governments must consider these trade-offs and adopt new technologies at a pace that the UK's economy and society can absorb.

Addressing skills shortages and workforce retraining

Talent development

Given the rapid development of emerging technologies and the increasing demand for data-related talents, the UK needs to emphasise multi-disciplinary technical skills and ICT-related competences. Education and training policies must deliver the new skills needed. Skills programmes should respond to changing industry demands, and specific schemes should retrain workers to adapt to changing conditions.

The government needs to encourage higher education institutions (HEIs) to launch new specialist undergraduate degrees, as well postgraduate programmes in advanced ICT-related FTL fields. Funding schemes, such as doctoral training centres or scholarships, support cutting-edge research in this area. The role of HEIs in engineering and management sciences was instrumental in the successful development of India's IT sector (Arora & Athreye, 2002). In China, in response to the great demand for logistics expertise, over 284 universities offer logistics management programmes, and 58 universities provide classes in logistics engineering (PwC, 2012).

Professional training and development programmes provided by trade or professional bodies, such as CILT, FTA, CII, IEEE and IATA,[17] also play an important role in responding to short- or medium-term skills development and retraining. Business-led digital skills programmes are also important (such as Google's digital garage initiative and Amazon Web Services' re:Start programme). Recognising the need to orchestrate various approaches, the UK Digital Strategy 2017 commits to establishing digital skills partnerships to enable a collaborative and coordinated approach to digital skills development. The freight sector needs to make sure the specific skills needed for freight are represented in this partnership.

Talent acquirement

To attract talent to the UK's freight sector, the government needs to work with key stakeholders to improve the sector's image, as the sector is viewed as unattractive by most job seekers (FTA, 2017; PwC, 2012). Attracting talent from outside the UK is even more challenging, given the added uncertainties of our future trading relationships. Clear employment and immigration policies are needed here.

[17] CILT: Chartered Institute of Logistics and Transport; CII: Charted Institute for IT; IEEE: The Institute of Electrical and Electronics Engineers; FTA: Freight Transport Association; IATA: International Air Transport Association

Making cybersecurity a top priority

Cybercrime leads to data breaches, financial crimes, market manipulation and theft of personal data, and poses risks to public safety and security. According to the National Crime Agency report (NCA, 2017), within three months of the creation of the National Cyber Security Centre (NCSC) in June 2017, the UK was hit by 188 high-level attacks that were serious enough to warrant NCSC involvement, and countless lower level ones, indicating that cybercrime is increasingly aggressive and frequent. The vulnerability of the freight system was clearly illustrated by the recent case of the NotPetYa cyberattack on the world's largest container shipping line, Moller-Maersk, in June 2017. The attack affected all its business units' operations and resulted in $300 million of lost revenue (Milne, 2017).

The rising number of IoT devices increases security risks because many connected devices have less secure software and are vulnerable to malware. Millions of insecure IoT devices are connected to the internet and have become the 'botnet of things', presenting 'a serious challenge to cyber security for a considerable time to come' (NCA, 2017, p.8). The government has a large part to play in promoting smart-device security and developing standards. Equally, cloud computing and social networks are not immune to cybercrime. DLT, by its nature, has no single point of failure, and is more resilient. However, its most popular application so far, Bitcoin, has been exploited by dark webs such as Silk Road for illegal purposes. The biggest challenge is that unlike the internet, DLTs have no sophisticated governance system in place.

Collaboration between industry, law enforcement and government is the only way the UK can successfully outpace cybercriminals. The government will need to invest in research to foster innovation in cybersecurity. It will also need to work closely with global counterparts and the business community to adapt to new threats, and share best practice and technological solutions. Regulators may need to mandate standards for securing consumer data. The General Data Protection Regulation introduced in May 2018 may help drive improvements in cyber risk management, as it requires unambiguous consent for data collection and compels companies to erase individual data on request. In the freight sector, companies at the forefront of managing cybersecurity could utilise NCSC guidance or a series of standards on IT and cybersecurity established by BSI Group,[18] the UK's standards body. They also need to take a holistic approach to building their digital vigilance and resilience (Wang, 2017).

Developing standards

Standards allow all parties in IT transactions to 'speak the same language' and are key to ensuring interconnectivity and interoperability. Open standards facilitate collaborative approaches, which can speed innovation and lower technology costs.

[18] BSI Group offers quite a comprehensive set of standards for IT and cybersecurity (see https://www.bsigroup.com/en-GB/Cyber-Security/Cyber-security-for-SMEs/Standards-for-IT-and-cyber-security/#BSI-standards) although these may need updating to accommodate new and emerging technologies.

BSI and Innovate UK began to work together to create new standards earlier in the development of new technologies (albeit not yet in ICT) in 2013. The underlying rationale is that 'By creating standards early in the emergence of new technologies, the UK can become the leader in these areas and gain "first mover advantage"' (Bsigroup.com).[19] However, for a disruptive innovation, it may be more desirable to retain as much variety as possible until it becomes clear what the winning technology will be, otherwise there is a risk of suboptimal development (Tait & Banda, 2016).

Determining the right timing for standardisation is challenging. The government should work closely with the following organisations to keep an abreast of technological developments to seize the right moment for standardisation:

- national, European and international standardisation bodies (e.g. BSI, GS1, ISO and IEEE),[20] which release formal standards;
- industry consortia (e.g. IETF, W3C, OASIS),[21] which develop informal standards; and
- technology service providers (e.g. Microsoft, IBM, SUN), which develop proprietary *de facto* standards.

Innovative government initiatives on standardisation have been observed in practice, such as Germany's integration of standardisation processes within the German innovation system and the USA's subcommittee on standards within the National Science & Technology Council (O'Sullivan & Brevignon-Dodin, 2012). The main motivation for such policy interests are to enable technological development, support government procurement needs and aid the effective allocation of R&D investment in emerging technologies. Proactive, strategic and systematic involvement by the UK government could potentially lead to economic competitiveness, growth and employment.

Although we do not intend to provide an exhaustive examination of standards developments, we showcase some important perspectives of standardisation below, focusing on DLT (less mature) and cloud computing (more established).

DLT standards

In the area of DLT, ISO formed the ISO Technical Committee 307 in 2016 to begin the process of creating the protocols upon which global blockchains can be built (ISO, 2016). In total, 10 working groups were established to explore important elements of blockchain and DLT, such as reference architecture, use cases, user identity, security and privacy, smart contracts, interoperability and governance. Industry-led activities on open standard development are mostly evident in IBM's substantial efforts through its Hyperledger initiative, launched in 2015. Hyperledger is an open-source collaborative effort created to advance cross-industry blockchain technologies. It is a global collaboration, hosted by The

[19] See details via https://www.bsigroup.com/en-GB/about-bsi/uk-national-standards-body/BIS-Exploring-new-areas-with-government-funding/projects/Innovate-UK-and-emerging-technologies/.
[20] GS1: Global Standards One; ISO: International Standards Organization; IEEE: The Institute of Electrical and Electronics Engineers
[21] IETF: Internet Engineering Task Force; W3C: World Wide Web Consortium; OASIS: The Organization for the Advancement of Structured Information Standards.

Linux Foundation, and includes over 190 members in finance, banking, IoT, supply chain, manufacturing and technology.

Despite these early efforts and general recognition of the importance of standards in ensuring interoperability, security and governance, a recent report commissioned by BSI Group highlighted that it may be too early to think about standards related to the technical aspects of DLT (Deshpande et al., 2017). The report further argues that once the technology is more mainstream and a better understanding of its strengths and weaknesses emerges, the priorities for standards will become clearer.

Cloud computing standards

Cloud computing has greater maturity and has made further progress in standardisation. For example, standards on reference architecture (ISO/IEC 17789:2014) and data management interface (ISO/IEC 17826:2016) have been developed by ISO,[22] with others still ongoing, such as standards for service level agreements (ISO/IEC 19086-1/2/3/4) and distributed application platforms and services (ISO/IEC DIS 20933). The USA's National Institute of Standards and Technology (NIST)[23] has proposed a list of cloud-computing-related standards. However, as is generally the case with emerging technologies, the global cloud computing standardisation landscape is complicated. A mapping exercise conducted the European Telecommunications Standards Institute (ETSI) has identified over 20 standard-setting organisations and industry associations that have or are in the process of developing cloud-computing standards and specifications (ETSI, 2013, p. 30). Each organisation applies its own rules, processes and terminology to the process of developing standards.

In addition to technology-specific standards, there are important developments on more generic standards. For instance, the development of the Universal Business Language version 2.1 was adopted in 2015 as an ISO standard (ISO/IEC 19845:2015). This defines a generic XML interchange format for business documents that can be restricted or extended to meet the requirements of particular industries. This has important implications for the FTL sector, as the standard ensures data interoperability and supports legacy systems as well as sector-specific systems such as Telematics Applications for Freight Services (TAFS) and River Information Services (RIS).

Finally, it is worth noting that there is no one best way of organising standardisation of emerging technologies. Standardisation is a complex and multi-layered activity that involves multiple stakeholders who differ in their objectives, strategies, resources and capabilities. It is dynamic, since there is a need for continuous adjustment to cope with technical progress. In the early stages, attention tends to be paid to terminology and semantics before effort gradually shifts towards interface and interoperability standards, and eventually standards associated with quality and compatibility. Governments could play various roles in standards development: as convener/coordinator, technical leader, participant agency, facilitator, adopter, technical advisor or interested observer (O'Sullivan & Brevignon-Dodin, 2012).

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[22] See details of standards: 35.210 – Cloud computing at https://www.iso.org/ics/35.210/x/

[23] See NIST's cloud-computing-related publications at https://www.nist.gov/itl/nist-cloud-computing-related-publications

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Appendix A: Selection of industrial reports consulted

List of reports consulted (non-exhaustive)

Sector-specific reports

1. Arup: Future of highways 2014
2. Arup: Future of rail 2050
3. Arup: Future of transport UK
4. Arup: The future of retail 2012
5. Freight Transport Association: Logistics report 2017
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Appendix B: Differences between VR, AR and MR

Virtual reality (VR) is a three-dimensional, computer-generated environment that can be explored and interacted with by a person,[24] hence offering a full immersive experience. Whereas VR immerses the senses completely in a world that only exists in the digital realm, augmented reality (AR) takes the real world of the present and projects digital imagery and sound into it (for example by overlaying a computer-generated image on a user's view of the real world). The information display and image overlay by AR are context sensitive, which means that they depend on the observed objects. Technically, AR can be defined as 'a medium in which digital information is overlaid on the physical world that is in both spatial and temporal registration with the physical world and that is interactive in real time' (Craig, 2013, p. 20). AR sometimes is defined as a special case (or subset) of VR reality. 'MR' (mixed reality), also referred to as hybrid reality, is a term coined by technology companies Intel and Microsoft to refer to 'the merging of real and virtual worlds to produce new environments and visualisations where physical and digital objects co-exist and interact in real time'. Figure 7 summarises the key differences between VR, AR and MR.

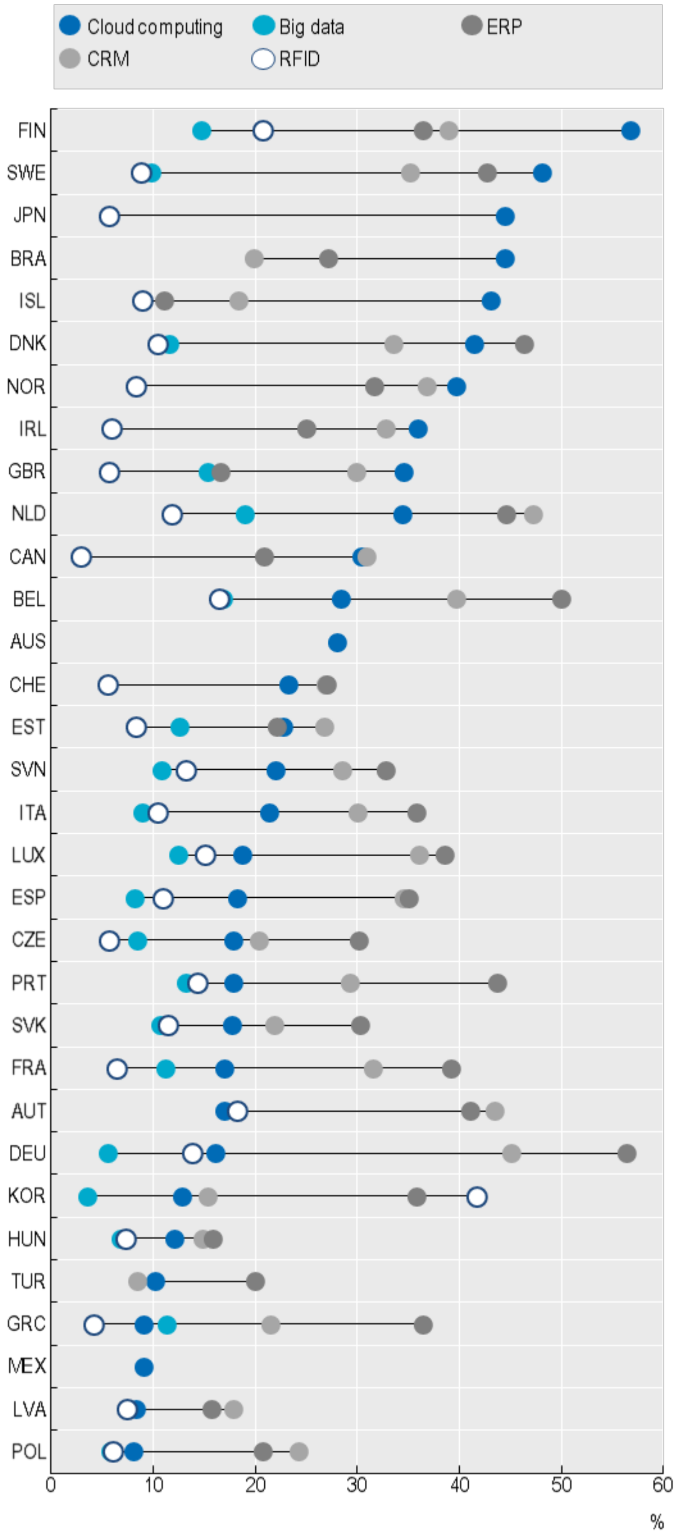
Figure 7: Key differences between VR, AR and MR

	Virtual reality (VR)	Augmented reality (AR)	Mixed/merged reality (MR)
Display device	Special headset or smart glasses	Headsets optional	Headsets optional
Image source	Computer graphics or real images produced by a computer	Combination of computer-generated images and real-life objects	Combination of computer-generated images and real-life objects
Environment	Fully digital	Both virtual and real-life objects are seamlessly blended	Both virtual and real-life objects are seamlessly blended
Perspective	Vitual objects will change their position and size according to the user's perspective in the virtual world	Virtual objects behave on basis of user's perspective in the real world	Virtual objects behave on basis of user's perspective in the real world
Presence	Feeling of being transported somewhere else with no sense of the real world	Feeling of still being in the real world, but with new elements and objects superimposed	Feeling of still being in the real world, but with new elements and objects superimposed
Awareness	Perfectly rendered virtual objects can't be distinguished from the real deal	Virtual objects can be identified by their nature and behaviour, such as floating text that follows a user	Perfectly rendered virtual objects can't be distinguished from the real deal

Source: McMillan et al., 2017

[24] Source: www.vrs.org.uk (2013)

Appendix C: Global spread of emerging technologies



	Country code	Cloud computing (%)	Big data (%)	Country Name
	FIN	56.9	14.8	Finland
	SWE	48.2	9.9	Sweden
	JPN	44.6	#N/A	Japan (2015)
	BRA	44.6	#N/A	Brazil
	ISL	43.1	#N/A	Iceland (2014)
	DNK	41.6	11.7	Denmark
	NOR	39.7	#N/A	Norway
	IRL	36.1	#N/A	Ireland
	GBR	34.7	15.4	United Kingdom
	NLD	34.5	19.1	Netherlands
	CAN	30.5	#N/A	Canada (2013)
	BEL	28.5	17.0	Belgium
	AUS	28.2	#N/A	Australia (2015)
	CHE	23.4	#N/A	Switzerland (2015)
	EST	22.8	12.7	Estonia
	SVN	22.2	11.0	Slovenia
	ITA	21.5	9.0	Italy
	LUX	18.8	12.5	Luxembourg
	ESP	18.3	8.3	Spain
	CZE	18.0	8.5	Czech Republic
	PRT	17.9	13.4	Portugal
	SVK	17.9	10.8	Slovak Republic
	FRA	17.1	11.3	France
	AUT	17.0	#N/A	Austria
	DEU	16.3	5.7	Germany
	KOR	12.9	3.6	Korea (2015)
	HUN	12.2	7.0	Hungary
	TUR	10.3	#N/A	Turkey
	GRC	9.2	11.4	Greece
	MEX	9.1	#N/A	Mexico (2012)
	LVA	8.4	#N/A	Latvia
	POL	8.2	5.9	Poland

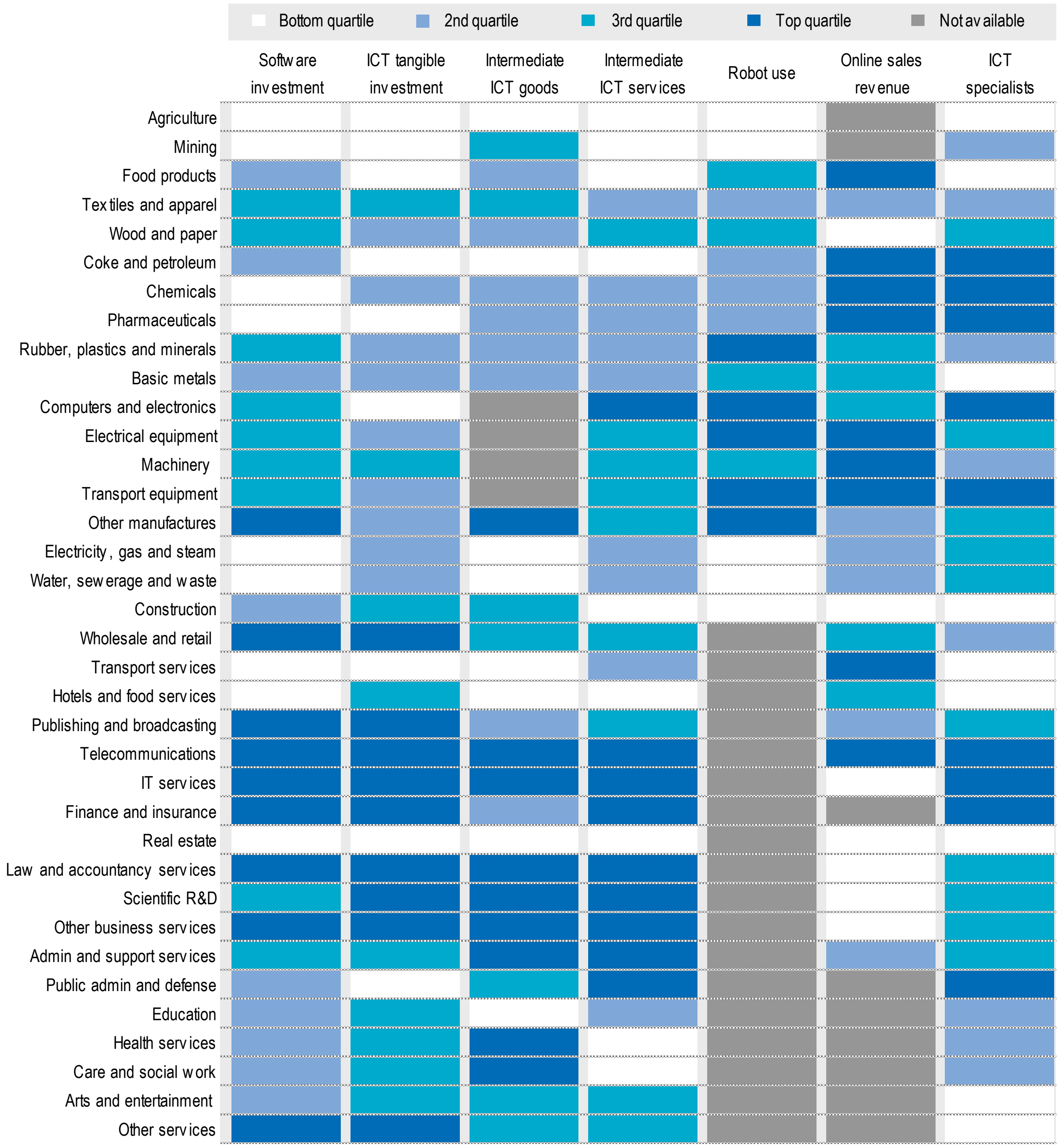
Note:

Cloud computing: For Canada, data refer to 2012 and to enterprises that have made expenditures on “software as a service" (e.g. cloud computing). For Mexico, data refer to

For countries in the European Statistical System, data on e-purchases and e-sales refer to 2015.
For Australia, data refer to the fiscal year 2014/15 ending on 30 June.
For Canada, data refer to 2013 except cloud computing (2012).
For Iceland, data refer to 2014.
For Japan, data refer to 2015 and include businesses with 100 or more employees instead of ten or more.
For Korea, data refer to 2015 except cloud computing (2013).
For Switzerland, data refer 2015 and to businesses with five or more employees instead of ten or more.

Source: OECD, 2017

Appendix D: Taxonomy of sectors by quartile of digital intensity, 2013–15



Source: OECD, 2017

Note: The dataset (in MS Excel format) is available from http://dx.doi.org/10.1787/888933617434

For each indicator, sectors are ranked by their value as an average across countries and years. The sectors with the highest intensity (top quartile) are coloured dark blue, while those with the lowest intensity are coloured white. Data on robot use is not available for services other than utilities and construction (i.e. all ISIC Rev.4 services above 43), while online sales data is not available for Agriculture (Division 1–3), Mining (5–9), Financial services (64–66) and all sectors numbered above 84 in ISIC. Purchases of ICT intermediate goods by the machinery manufacturing sectors are not considered, to avoid mismeasurement.

Appendix E: Country connectedness index and overall flows 2014

MGI Connectedness Index

Country connectedness index and overall flows data, 2014
Rank of participation by flow as measured by flow intensity and share of world total

Connectedness index rank 1–10 11–25 26–50 >50 **Flow intensity** 100+ 70–99 <70

			Connectedness Index rank					Flow value[1]	Flow intensity[2]
Rank	Country	Score	Goods	Services	Finance	People	Data	$ billion	% of GDP
1	Singapore	64.2	1	2	2	12	6	1,392	452
2	Netherlands	54.3	3	3	6	21	1	1,834	211
3	United States	52.7	7	7	3	1	7	6,832	39
4	Germany	51.9	2	4	8	3	2	3,798	99
5	Ireland	45.9	32	1	1	28	9	559	227
6	United Kingdom	40.8	13	5	5	6	3	2,336	79
7	China	34.2	4	16	4	82	38	6,480	63
8	France	30.1	11	8	9	7	4	2,262	80
9	Belgium	28.0	5	6	33	33	8	1,313	246
10	Saudi Arabia	22.6	20	28	27	2	53	790	106
11	United Arab Emirates	22.2	6	23	17	4	46	789	196
12	Switzerland	18.0	12	11	10	17	13	848	115
13	Canada	17.3	16	22	11	11	18	1,403	79
14	Russia	16.1	21	25	18	5	25	1,059	57
15	Spain	14.4	25	13	19	14	16	1,105	79
16	Korea	14.0	8	12	28	50	44	1,510	107
17	Italy	13.4	17	18	24	16	19	1,587	74
18	Sweden	13.0	29	14	22	31	5	572	100
19	Austria	11.7	26	17	31	20	12	470	108
20	Malaysia	11.6	9	19	25	26	43	610	187
21	Mexico	10.7	14	63	34	18	41	1,022	80
22	Thailand	10.7	10	15	36	44	64	605	162
23	Kuwait	10.6	37	46	13	13	75	306	153
24	Japan	10.5	15	20	12	81	20	2,498	54
25	Kazakhstan	10.0	48	73	41	8	57	176	83
26	Ukraine	9.8	38	39	87	10	34	133	101
27	Australia	9.7	30	34	21	15	33	825	57
28	Denmark	8.9	35	9	32	41	11	369	108
29	Jordan	8.8	73	50	75	9	83	50	138
30	India	8.5	24	10	35	58	70	1,316	64
32	Czech Republic	7.5	18	33	57	59	15	397	193
34	Poland	7.0	23	31	47	34	22	585	107
35	Hungary	6.8	22	30	26	62	17	287	209
36	Norway	6.0	36	24	20	46	24	458	92
37	Vietnam	5.7	19	54	45	103	61	350	188
39	Finland	5.5	46	27	23	70	10	390	144
40	Portugal	5.5	47	36	30	23	31	255	111
41	Turkey	5.1	28	40	53	38	29	521	65
43	Israel	4.9	51	32	49	24	56	248	82
44	Brazil	4.5	41	38	14	125	30	869	37
45	Chile	4.1	45	58	16	102	27	239	92
47	Greece	4.1	60	29	54	35	42	160	67
48	New Zealand	3.9	67	48	61	25	51	130	63
51	Indonesia	3.4	31	49	38	106	76	504	57
53	South Africa	3.3	34	57	52	64	80	277	79
54	Philippines	3.2	54	41	44	52	67	230	81
64	Morocco	2.6	58	43	74	56	65	104	97
73	Egypt	2.2	68	42	69	73	71	158	55
83	Nigeria	1.9	55	76	48	128	98	268	47
86	Peru	1.8	62	88	51	104	49	122	60
118	Kenya	1.3	100	84	127	119	91	35	58

1 Flows value represents total goods, services, and financial inflows and outflows.
2 Flow intensity represents the total value of goods, services, and financial flows as a share of the country's GDP.

Source: McKinsey, 2016

Appendix F: World Bank Logistics Performance Index Global Ranking Top 30 2016

Country	LPI Rank	LPI Score	Customs	Infrastructure	International shipments	Logistics competence	Tracking & tracing	Timeliness
Germany	1	4.23	4.12	4.44	3.86	4.28	4.27	4.45
Luxembourg	2	4.22	3.9	4.24	4.24	4.01	4.12	4.8
Sweden	3	4.2	3.92	4.27	4	4.25	4.38	4.45
Netherlands	4	4.19	4.12	4.29	3.94	4.22	4.17	4.41
Singapore	5	4.14	4.18	4.2	3.96	4.09	4.05	4.4
Belgium	6	4.11	3.83	4.05	4.05	4.07	4.22	4.43
Austria	7	4.1	3.79	4.08	3.85	4.18	4.36	4.37
United Kingdom	8	4.07	3.98	4.21	3.77	4.05	4.13	4.33
Hong Kong, China	9	4.07	3.94	4.1	4.05	4	4.03	4.29
United States	10	3.99	3.75	4.15	3.65	4.01	4.2	4.25
Switzerland	11	3.99	3.88	4.19	3.69	3.95	4.04	4.24
Japan	12	3.97	3.85	4.1	3.69	3.99	4.03	4.21
United Arab Emirates	13	3.94	3.84	4.07	3.89	3.82	3.91	4.13
Canada	14	3.93	3.95	4.14	3.56	3.9	4.1	4.01
Finland	15	3.92	4.01	4.01	3.51	3.88	4.04	4.14
France	16	3.9	3.71	4.01	3.64	3.82	4.02	4.25
Denmark	17	3.82	3.82	3.75	3.66	4.01	3.74	3.92
Ireland	18	3.79	3.47	3.77	3.83	3.79	3.98	3.94
Australia	19	3.79	3.54	3.82	3.63	3.87	3.87	4.04
South Africa	20	3.78	3.6	3.78	3.62	3.75	3.92	4.02
Italy	21	3.76	3.45	3.79	3.65	3.77	3.86	4.03
Norway	22	3.73	3.57	3.95	3.62	3.7	3.82	3.77
Spain	23	3.73	3.48	3.72	3.63	3.73	3.82	4
Korea, Rep.	24	3.72	3.45	3.79	3.58	3.69	3.78	4.03
Taiwan	25	3.7	3.23	3.57	3.57	3.95	3.59	4.25
Czech Republic	26	3.67	3.58	3.36	3.65	3.65	3.84	3.94
China	27	3.66	3.32	3.75	3.7	3.62	3.68	3.9
Israel	28	3.66	3.5	3.49	3.38	3.6	3.72	4.27
Lithuania	29	3.63	3.42	3.57	3.49	3.49	3.68	4.14
Qatar	30	3.6	3.55	3.57	3.58	3.54	3.5	3.83

The logistics performance (LPI) is the weighted average of the country scores on the six key dimensions:

Notes

1) Efficiency of the clearance process (i.e., speed, simplicity and predictability of formalities) by border control agencies, including customs;

2) Quality of trade and transport related infrastructure (e.g., ports, railroads, roads, information technology);

3) Ease of arranging competitively priced shipments;

4) Competence and quality of logistics services (e.g., transport operators, customs brokers);

5) Ability to track and trace consignments;

6) Timeliness of shipments in reaching destination within the scheduled or expected delivery time.

The scorecards demonstrate comparative performance—the dimensions show on a scale (lowest score to highest score) from 1 to 5 relevant to the possible comparison groups—of all countries (world), region and income groups. The details of the methodology can be found via https://lpi.worldbank.org/about.

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