CAN THE INTERNET OF THINGS IMPROVE THE SUSTAINABILITY OF ROAD FREIGHT TRANSPORT OPERATIONS?

By

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Abstract

The Internet of Things (IoT) and its enabling technologies are expected to revolutionise business operations and processes in the near future, through the creation of a network of connected equipment, vehicles and processes. However, the issues of barriers and drivers to using this technology by companies in road freight transport have not been addressed in any detail. This research aims to critically evaluate the barriers and drivers for the application of the IoT in the road freight transport industry, and investigate the use of IoT and associated technologies for achieving efficient, effective and potentially sustainable freight transport logistics operations. An extensive review of academic and industry literature on IoT and the application of IoT technologies to road freight transportation has been conducted, followed by a pilot questionnaire survey of the logistics and transport sector to identify the problems of implementation (if any), advantages, disadvantages, barriers, and drivers to implementing elements of IoT and the potential for these technologies to lead to sustainable road freight transport. Given the pilot survey questionnaire results, and the clear overlap with the academic literature, we conclude that there is clear scope for further investigation of IoT to improve sustainability in the road freight transport industry.

Keywords:

Internet of Things (IoT); freight transport; road freight; sustainability; logistics

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Abstract

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1. Introduction

Sustainable freight transport is an increasingly important area of logistics (Fürst and Oberhofer, 2012; Mattila and Antikainen, 2011). However, there are many barriers and drivers to achieving sustainability (WCED, 1987). For example, different countries have very specific operational constraints, limitations of road infrastructure in historic urban areas and barriers to dealing with road freight access at peak times (Zanni, and Bristow, 2010). These barriers can be offset by the main benefits of achieving sustainability which can include reduced fuel consumption, reduced costs, reduced emissions, reduced mileage, reduced vehicle and road wear and tear, reduced impact on congestion, and improved efficiency (Gilpin, et al., 2014; Liotta, et al., 2015). For example, IoT and its enabling technologies can enhance process efficiency by reducing human error, waste and non-value adding activities, which also helps to enhance environmental sustainability (Macaulay et al., 2015). However, these benefits cannot be achieved without considerable effort and a full knowledge of what is possible in different locations (Oberhofer and Fürst, 2013; Richardson, 2005).

The Internet of Things (IoT) offers an opportunity to use data which can be collected from Radio Frequency Identification (RFID), Machine to Machine Communications (M2M), Global Positioning Systems (GPS), Cyber Physical Systems (CPS), and cloud-based applications to help solve routing and transport problems (Ashton, 2009; Chaâri et al, 2016; Gubbi et al., 2013; Hamilton et al., 1993). The main benefits can be reduced fuel consumption, solving the travelling salesman's problem in real-time whilst dealing with interruptions to freight transport logistics from a range of external factors, such as travel disruption on the road network from accidents, road works, weather, congestion and supplier/customer schedule changes. The ability to communicate directly with freight transport also enhances the ability of the company to deal with quality problems such as temperature of the goods being transported and security issues (Li et al., 2016; Gilchrist, 2017).

Currently there is some application of the IoT in port logistics, but the application of IoT in road freight transport remains largely under-developed, thus highlighting an academic research gap in this field (Evangelista et al., 2013; Goldman and Gorham, 2006). This affords an opportunity for freight transport operators to improve the sustainability and efficiency of their operations, whilst providing a competitive advantage in the marketplace for early-adopters of this technology.

1.1 Aims and Objectives

This research aimed to:

- Critically evaluate the barriers and drivers for the application of the IoT in the road freight transport industry from a literature review.
- Determine the barriers and drivers to implementing IoT in UK road freight transport logistics businesses via an initial pilot survey followed by a much larger questionnaire survey.
- Investigate the potential for the use of IoT and associated technologies for achieving efficient, effective and potentially sustainable freight transport logistics operations.
- Evaluate the potential for IoT to improve sustainability in this industry sector.

1.2 Research Approach

It is important to note that this research project is at a complex intersection of three strands of work. That is, application of the Internet of Things, Road Freight Transport and

Sustainability. Each of these areas overlap and increasingly the IoT is becoming a pervasive technology and so it was necessary to understand the technologies which support the IoT.

The research followed the normal procedure of literature review, development of an interview questionnaire, development of a pilot survey questionnaire, testing, modification of the questionnaire and full survey (Robson, 1993; Hussey and Hussey, 1997). However, only the pilot results are reported here and the full survey is to be carried out at a later date.

A review of academic and industry literature on IoT and the application of IoT technologies was conducted. From this review, the barriers and drivers to implementing IoT technology were identified and used to create an interview questionnaire and a pilot questionnaire survey. This pilot survey contained a combination of closed and open ended questions, with the open response questions included to offer an opportunity for respondents to comment on the problems of implementation (if any), advantages, disadvantages, barriers, and drivers to implementing the IoT elements and integrating them into a workable system.

To investigate the drivers and barriers to IoT in the road freight transport industry an online version of the pilot questionnaire survey was distributed to the freight industry through personal contacts and advertised through the Fleet Operator Recognition Scheme (FORS) eNews which is distributed to freight transport operators and FORS scheme members. As a pilot survey the response rates were intended to be relatively low and to check that the questionnaire worked well enough to warrant a much larger survey in the UK and internationally. Piloting a questionnaire is essential before launching a full questionnaire to ensure that the instrument has no errors, addresses all the relevant topics, and is clear and easy for respondents to answer (Robson, 1993; Hussey and Hussey, 1997). As a pilot survey the data analysis was a simple thematic comparison against the literature review at this stage. A number of theoretical, analytical frameworks (identification of drivers and barriers) and comparative tables were produced to make sense of this complex area of research and its application to road freight transport in the UK (see Figure 1).

2. Literature Review

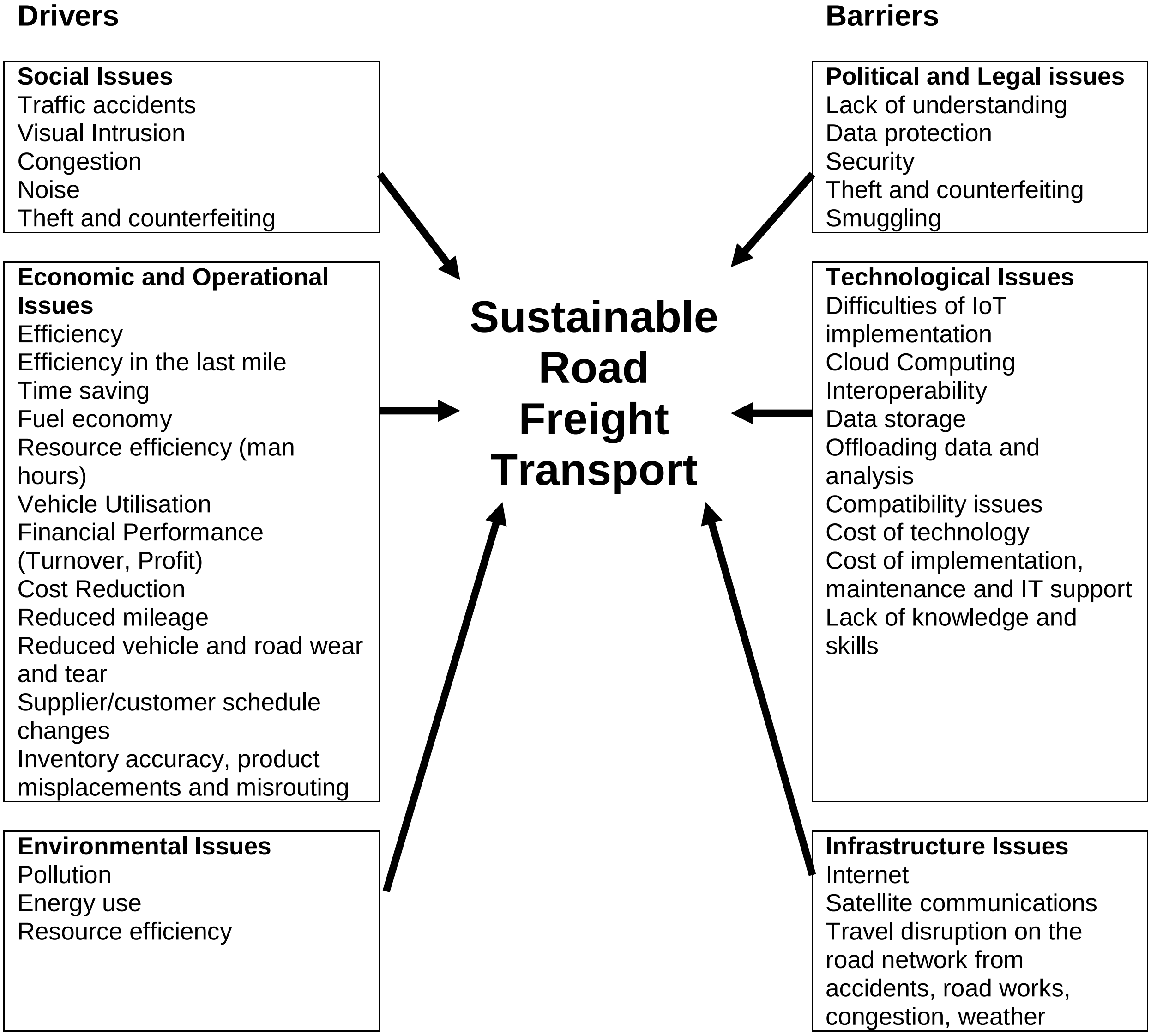
There are various economic, operational, social and environmental benefits of using IoT technology, making it an ideal mechanism to improve the sustainability of the freight transport sector. For the purposes of this research project an extensive literature review was carried out to determine the current extent of research into the respective fields of the IoT and sustainable freight transport, and whether any ties exist between these fields of research. The literature review includes a summary table of IoT technologies, their use in freight transport and sustainability (see table 1) and the drivers and barriers to the use and adoption of IoT technology (see tables 2 and 3) in the findings and discussion.

2.1 Defining the Internet of Things and Associated Technologies

The concept of the Internet of things (IoT), developed by Kevin Ashton in 1999 (Gubbi et al., 2013), refers to a global environment where the Internet is at the centre of connectivity for all devices, machinery and systems (Ashton, 2009). There are many definitions of IoT and these definitions have changed over time as the technology has developed (Li et al., 2016). A working hybrid definition which encapsulates many of the concepts of IoT can be given:

"*The Internet of things is the networking of physical devices, buildings, transport, other facilities, objects and things which have embedded electronics, software, sensors, actuators and devices for communicating with the Internet which enables these things and objects to collect and exchange data often for the purposes of monitoring, sensing and controlling devices remotely*." (Chaâri et al., 2016; Gubbi et al., 2013; Hsu et al., 2015; Li et al., 2016).

Figure 1. Drivers and Barriers to the Implementation of Internet of Things in Road freight Transport



Thus, IoT connects physical devices including sensors, actuators, RFID readers etc., to each other and to the Internet. In an IoT enabled environment, devices and machinery can communicate and feedback valuable information about their status and performance through machine to machine (M2M) communications and cyber physical systems (CPS) (Kagermann et al., 2013).

The Internet of Things (IoT) concept is the idea of a variety of *things* or *objects* – such as Radio-Frequency Identification (RFID) tags, sensors, actuators, mobile phones, etc. – which, through unique addressing schemes, are interconnected and cooperate with neighbouring devices to reach common goals (Atzori et al., 2010). IoT connects business systems with physical devices, enabling highly integrated business processes. This brings about the advantages of rapid information flow, greater responsiveness and improved decision-making (Johansson, 2012). Using sensors, connectivity and cloud computing technology, people will be connected to the right information, and will have access to the latest data from any location (Chaâri et al., 2016; Hsu et al., 2015). New levels of interconnectivity in IoT will result in the generation of new data. This data can be collected and analysed by big data analytics and can be turned into valuable information to support managerial decision-making (Macaulay et al., 2015).

2.2 Application of Internet of Things Technologies to Freight Transport

The integration of data, systems and processes is achieved by a number of technological innovations, some examples of which are outlined below:

Cyber Physical Systems (CPSs) is one of the main enablers of IoT as it allows connections between the physical and virtual world through the connectivity of software and hardware (Blau, 2014). CPSs allow for the capture of data from different points within the supply chain to enhance the efficiency and responsiveness of transportation processes (Chung and Swink, 2009).

Machine to Machine (M2M) Communications have created smart environments where machines, devices and products autonomously communicate and control each other. This capability leads to enhanced information sharing between devices and machinery, and streamlines supply chain activities improving efficiency (Kagermann, 2013; Blau, 2014). M2M communications technology has enabled connectivity and allowed for effective information exchange between vehicles, people and freight transportation systems (Meyer et al., 2014; Macaulay et al., 2015).

Radio-Frequency Identification (RFID) tags and GPS locators are being used by logistics providers on pallets, cargo, and logistics infrastructure to provide advanced tracking and monitoring capabilities (Amini, 2007). RFID tags transmit data and information about the condition of products as they pass reader devices (Macaulay et al., 2015; Meyer et al., 2014). They have been used to protect products against theft and counterfeiting, thus increasing inventory accuracy with fewer product misplacements and misrouting (Zacharewicz et al., 2011; Kosasi et al., 2014). Near Field Communication (NFC) has evolved from RFID technology and performs as one part of a wireless link, enabling wireless data transfer with other smart devices (Zacharewicz et al., 2011).

Sensors allow monitoring conditions (e.g. humidity, temperature, pressure, etc.), and can report to truck drivers if any thresholds are passed. Sensors enable a high level of security and product safety by alerting drivers if someone attempts to tamper with cargo and pallets (Li et al., 2016; Macaulay et al., 2015).

Thus, IoT will bring about significant advantages in logistics and freight transportation, from enabling more efficient transportation, promising operational efficiency and productivity (Johansson, 2012; Hsu et al., 2015), to creating smart 'last mile' delivery options for customers (McKinnon et al., 2015).

2.3 Difficulties with the Internet of Things for Freight Transport

There are several problems facing the use of IoT in road freight transport including data compatibility, data storage, access to cloud computing and issues of security (Li et al., 2016; Gilchrist, 2017). The integration of a wide range of devices requires a robust set of standards, data exchange protocols and compatibility of software applications (Chaâri et al., 2016; Gubbi et al., 2013; Hsu et al., 2015). The large amount of data generated by integrated systems has led to data storage problems and is the result of continuous, direct interaction with the real world. Chaâri et al., (2016, p.262) suggest that "…*the exponential growth in the amount of data generated by cyber-physical systems needs a revolutionary storage strategy*." Most CPSs are resource constrained with limited processing and data storage capacities leading to the need to offload data and computations to more powerful computing machines with greater data storage capacity. CPSs are heterogeneous in nature with interoperability problems and challenges which makes it difficult to access these systems from the Internet. Thus, these problems can be summarised as (i) need to offload intensive computation; (ii) storing and analysing large amounts of data; and (iii) enabling seamless access through virtual interfaces

(Chaâri et al., 2016). However, these technical challenges will likely be solved over the next few years and real-time data processing will be possible within a large integrated high-speed network.

Chaâri et al., (2016, p. 263) suggest that cloud computing offers a solution and they give a simple definition of cloud computing as: "…*having access to all your applications and data from any network connected device.*" The fact that all of the technologies involved in IoT and cloud computing are based on data exchange on the Internet means that security, privacy and hacking are likely to be major problems for businesses wishing to develop IoT solutions for road freight transport and other applications (Li et al., 2016; Gilchrist, 2017).

2.4 Sustainability

The most widely used definition of sustainable development originates from the 1987 United Nations Brundtland Report, which defines sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987). Although, heavily criticised (Henriques and Richardson, 2004) this definition is commonly used. Sustainability and sustainable development are problematic as they appear to be rather contradictory and difficult to put into practice. The Department of the Environment, Transport and the Regions (DETR) produced a consultation documents on 'Sustainable Business' (DETR, 1998) in response and outlined the importance of sustainable development for all sectors of society which were based on four objectives:

(1) Social progress which recognises the needs of everyone;

(2) Effective protection of the environment;

(3) Prudent use of natural resources; and

(4) Maintenance of high and stable levels of economic growth and employment.

While similar to the Triple Bottom Line of Social, Economic and Environmental performance measures for businesses the definition used in the Triple Bottom Line is: "*Sustainability is the principle of ensuring that our actions today do not limit the range of economic, social and environmental options open to the future*" (Elkington, 1997).

2.5 Sustainable Freight Transport

Sustainable freight transport aims to balance the economic, social and environmental dimensions of the freight transport sector in an integrated manner to ensure synergies, complementarities and coherence (United Nations, 2015). However, there are many environmental externalities associated with road freight transport including noise pollution, visual intrusion, community severance, congestion (European Commission, 2009), and air pollution resulting from reliance on using traditional combustion engines in vehicles (WHO, 2003; Freight Transport Association, 2014; Royal College of Physicians, 2016). These environmental issues are directly linked to the large amount of energy used in this sector which is mostly derived from fossil fuels (McKinnon and Piecyk, 2009; Piecyk and McKinnon, 2010).

For the freight transport industry the issue of sustainability is becoming increasingly important as logistics businesses attempt to differentiate themselves from competitors (Evangelista, 2014; Evangelista et al., 2013) in an increasingly competitive and globalised marketplace. However, sustainability can be considered as a much broader concept by taking into account the economic, social and environmental implications of logistics activities (Macharis, 2014; McKinnon, 2010, Elkington, 1997; Henriques and Richardson, 2004).

Macharis (2014) propose a number of possible measures that could be implemented to foster sustainable logistics practices, classified as the four A's of sustainable logistics as: Awareness, Avoidance, Acting and shifting, and Anticipation.

1) **Awareness** – create more awareness by measuring the effects of logistics activities, especially through monetising the effects as costs to feed into a social cost-benefit analysis, thus determining how beneficial a particular project might be for society. Alternatively, certification schemes for transport operators can be used to demonstrate levels of environmental awareness, and actively promote sustainable operations.
2) **Avoidance** – identifying opportunities to avoid the use of freight transport can be difficult, as in reality many goods need to be physically moved to their final destination. However, new technological innovations have brought about opportunities to limit transportation. For example, 3D printing and digital music downloads both reduce the number of physical items requiring freight transportation. Similarly, improvements to packaging have helped optimise lorry capacity, and the opportunity to use larger vehicles increases the load factor, therefore minimising the number of lorry trips required.
3) **Acting and Shifting** – seeking suitable opportunities for modal shift from road to rail or water freight, or at least incorporate intermodal freight transport where possible. However a case-specific approach to modal shift should be adopted to maximise options available locally. Alternatively, shifting freight transport could also include mechanisms to avoid the road network during peak-times, for example advocating a shift towards night-time or off-peak deliveries.
4) **Anticipation** – perhaps most relevant to this research, is the anticipation of a shift towards new technologies applicable to the road freight sector. New vehicle technology could reduce emissions from road freight transport considerably. There are also many opportunities for IoT technologies to be used, such as sensors that assist with the enforcement of parking in loading/unloading bays; and incorporating big data and ICT into the supply chain to improve delivery scheduling and load planning.

Macharis (2014) also proposes a potential fifth 'A' of sustainable logistics, **Actor** involvement, since the involvement of key stakeholders and freight actors is essential for the successful implementation of new logistics concepts.

2.6 Potential for IoT and Associated Technologies in Logistics and Freight Transport

In general, digitization and automation resulting from the application of IoT is expected to bring efficiency benefits and growth opportunities, leading to a significant competitive advantage for organizations (Kagermann et al., 2013). IoT will allow flexibility and responsiveness, enabling companies to embrace changes to adapt to volatile business environments (Coetzee and Eksteen, 2011; Sternberg and Andersson, 2014).

Addressing sustainability issues and achieving cost savings and efficiency benefits are amongst the most important challenges for freight transport businesses (Hsu et al., 2015). These factors have led to a dramatic increase in the complexity and dynamics of today's transport and logistics processes. Technological innovations such as the IoT, through the creation of a network of connected equipment, vehicles and processes, has enabled autonomous and real-time information processing and communication within a network. It has also decentralised operations within the freight transportation process and led to real time control of logistics activities (Macaulay et al., 2015).

2.7 Links between IoT, Road Freight Transport and Sustainability

This research aimed to provide links via the theoretical framework in figure 1, between IoT, road freight transport and sustainability. Table 1, below, summarises the application of these technologies in freight transport and their potential for improving sustainability in freight transport. It could be argued that IoT has the potential to address sustainability within road freight transportation. There are many opportunities to apply IoT as outlined earlier, however specifically it could benefit road freight transport sustainability through smart fleets, route management and employee safety and security.

2.7.1 Smart fleet

Management and transport planning can be enhanced with IoT by connecting transportation fleets with delivery planning personnel. This will lead to better communication and information sharing and will also optimize the return trips to improve efficiency and service in last mile delivery, which, in turn, will enable faster, more reliable and cost-effective delivery services for customers (Cheung et al., 2008). For example, global positioning technologies, such as GPS and Global System for Mobile Communications/General Packet Radio Service (GSM/GPRS) can identify various fleet positions and locations, enabling advanced fleet management, and effective real time communication between vehicles and their base.

2.7.2 Route Management

IoT can enable the analysis of road traffic patterns that can enhance planning and route allocation. Traffic analytics in combination with weather forecasts can provide valuable insights to the predictive monitoring system, facilitating transport route management for transportation fleets leading to improved responsiveness (Zacharewicz et al., 2011; Hsu et al., 2015). IoT can identify optimal capacity rates of assets by identifying and analysing the patterns of vehicle usage (Macaulay et al., 2015). IoT can help with avoiding bad weather conditions by enabling flexibility and fast rescheduling, and can determine alternative routes when anticipating traffic congestion or other disruptions along the route. Therefore, assigning real-time updates to routes and directions for drivers will be easier and faster.

2.7.3 Employee Safety and Security

IoT can play a significant role in drivers' health and safety by preventing potential collisions and alerting drivers when they are fatigued (Macaulay et al., 2015). Employee safety and security can also be improved leading to cost reductions for the company. Sensors attached to products or vehicles can monitor workers health, especially in hazardous environments, and warn them if danger is detected. In the future, it is possible that IoT will have the capability to lock a driver out of the vehicle when inappropriate driver behaviour is detected, thus ensuring product safety and integrity (Hsu et al., 2015).

IoT can also improve security by monitoring containers for unexpected opening that may occur due to improper storage, can detect theft, and inappropriate movement of products. A combination of sensors attached to products and vehicles can identify risks from imperfect storage, alert drivers to take corrective action, and thus reduce damage to products and injury to workers (Hsu et al., 2015).

Table 1. IoT Technologies, Freight Transport and Sustainability.

IoT Technology	Use in freight transport	Improving Sustainability of Freight Transport
Cyber Physical Systems (CPSs)	Allows connections between the physical and virtual worlds through the connectivity of software and hardware (Blau, 2014).	Enhances the efficiency and responsiveness of transportation processes (Chung and Swink, 2009)
Global Positioning Systems (GPS)	Allows for more flexible and efficient routing of freight vehicles using real-time digital map technology (Amini, 2007).	GPS technology can minimise traffic congestion levels and enhance efficiency (Zhan et al., 2011)
Radio Frequency Identification (RFID)	Allows the transmission of information, useful to identify items, without human intervention or physical connection (Amini, 2007; Zacharewicz et al., 2011)	Increases resource efficiency, particularly for tracking and tracing inventory during transit (Amini, 2007; Chaâri et al., 2016; Meyer et al., 2014).
Sensor technologies	Clear visibility on movement of goods, item level condition monitoring - temperature, humidity, lighting etc. (Macaulay et al., 2015)	Reduces waste (Castro et al., 2012), helps achieve CSR commitments (Zacharewicz et al., 2011), and enables real time visibility (Kosasi et al., 2014)
Machine to machine Communications (M2M)	Allows communications between products, pallets and logistics infrastructure and enables integration with transportation management systems (Macaulay et al., 2015).	Enhanced information sharing between devices and machinery, streamlines supply chain activities improving efficiency (Kagermann, 2013; Blau, 2014)
Cloud-based applications	Creates a collaborative and integrative platform for transportation processes (Chaâri et al., 2016).	Short-term prediction, effective proactive management of transportation (Hsu et al., 2015).
Intelligent vehicles - Maintenance on demand (MoDe)	Analytics used to automatically schedule maintenance checks, freight vehicles decide autonomously when and why they need maintenance (Cognizant 20-20 insights, 2014).	Reductions in harmful pollutants, improved fuel efficiency. (European Commission, 2009; WHO, 2003; Freight Transport Association, 2014; Royal College of Physicians, 2016)
Autonomous vehicles	Collision avoidance systems reduce traffic accidents involving freight vehicles with forward collision alerts and automatic brake activation (Fagnant and Kockelman, 2015)	Facilitates social sustainability of freight sector with fewer traffic accidents involving freight vehicles (Chaâri et al., 2016).

3. Findings and Discussion

The tentative results from an online pilot survey of freight transport operators has been used to identify the major barriers and drivers in applying and integrating the IoT technologies in road freight transport logistics companies. The main benefits of adopting IoT can include: reduced fuel consumption and dealing with interruptions to freight transport logistics from a range of external factors (such as travel disruption on the road network from accidents, road works, weather and supplier/customer schedule changes etc.). The ability to communicate directly with freight transport also enhances the ability of the operator to deal with quality problems and security issues (Li et al., 2016). However, integration of these IoT technologies currently appears to be under-developed and under-researched and faces a number of technological problems (e.g. limited capacity of devices, offloading data and analysis, interoperability and compatibility) (Chaâri et al., 2016). The terminology used and the various technologies applied require a high level of knowledge about information technology. From the preliminary qualitative assessment of the results, it would appear that currently many small operators in the industry do not have this expertise and this is a major barrier to the application and integration of these IoT technologies.

A number of different trends emerged from the pilot survey. Most of the firms surveyed are currently using some form of IoT technology or intend to use IoT technology in future. This illustrates, as was anticipated, that IoT technology is widely adopted by firms today. This trend is only going to continue with many of the respondents saying they are either "likely" or "very likely" to invest further in IoT technology.

There was good general agreement between the academic and industry literature and the responses obtained from the pilot questionnaire. This suggests that it is an area of research worth pursuing with a much larger questionnaire in the UK and internationally.

All respondents agreed that GPS location and track and trace technologies can have a positive impact on improving the sustainability of road freight operations (Amini, 2007; Lee and Lee, 2015). Perhaps this is due to such technologies being regarded as established, well-known, understood, affordable, readily available and familiar within the industry. Given this point it is possible that incremental adoption and implementation of newer and more advanced IoT technologies could improve the sustainability of road freight transport operations.

3.1 Drivers to Using the Internet of Things Technology

Table 2, below illustrates the differences between the views of practitioners in the freight transport industry and the academic literature in the area where the drivers to the use of IoT are concerned. The most frequently identified drivers of IoT technology amongst the respondents were operational efficiency and improved visibility, implying that the primary drivers of IoT technology are the associated business and operational benefits (Macaulay et al., 2015).

Comments from respondents regarding the relationship between IoT and sustainability had interesting points of view; for example, one respondent from the public sector suggested that:

"[sustainability was achieved by]…*improved efficiency in terms of fuel savings and time*."

One respondent from the construction industry also thought that sustainability would be achieved by "… *increasing efficiencies*…"

Another respondent from the aviation industry suggested that:

"[IoT was] …*critical for providing good quality data for accurate analysis of root causes and effects to allow the efficient and effective design of sustainable freight transport solutions*."

While other respondents thought that "…*tracking and driver safety*…" were part of sustainable freight transport operations. Clearly tracking, tracing and driver safety are important parts of freight transportation (Chaâri et al., 2016; Meyer et al., 2014; Macaulay et al., 2015) but a wider consideration of the drivers was offered by another respondent:

"*Benefits to employees* [of] *quality of life/work time* [the] *effect can be positive or negative, depending on type of employer and their ethos). Environmental and cost savings are clearly* *linked at present as evidenced in analysis/assessment and results [which] drive forward planning*."

Table 2. Drivers to Using the Internet of Things Technology

Drivers of Internet of Things technology (Literature Review)	**Drivers of Internet of Things technology (Pilot Survey Results)**
Lee and Lee (2015) outline that IoT can enhance profitability through operational efficiency improvements and decreased operating/ distribution costs.	Improved operational efficiency, reduced operating costs and enhanced profitability were identified by respondents.
Less labour intensive – RFID / autonomous vehicles (Zacharewicz et al., 2011)	Less labour intensive.
Improved visibility and connectivity (Lee and Lee, 2015)	Improved visibility and connectivity were thought to be important by respondents.
Improvements in road safety - 40% reduction in fatalities with the introduction of autonomous vehicles (Fagnant and Kockelman, 2015).	Improved road safety and safety of employees.
Improved journey time reliability using GPS systems (Gubbi et al., 2013)	Improved journey time reliability was thought to be important by respondents
Contractual obligations (Fleet Operator Recognition Scheme)	Contractual obligations can be met.
Reduced errors- RFID (Rekik et al., 2008)	Reduced errors
Environmental issues (McKinnon, 2010; McKinnon et al., House, 2013)	Reduced GHG emissions and other environmental improvements were expected by respondents largely by efficiency gains.

3.2 Barriers to Using the Internet of Things Technology

It is clear that there are many barriers to the use of IoT technologies largely to do with lack of knowledge of information technology, information systems security, cost for smaller logistics companies, difficulties of implementation and interoperability problems. Perhaps not surprisingly, the most frequently identified barriers to IoT technology were the costs (purchase, implementation and maintenance) associated with integrating IoT into a firm's operations (see table 3). It is clear that there are many barriers to the use of IoT technologies both in the academic literature and from the point of view of practitioners surveyed.

These barriers are largely to do with lack of knowledge of information technology, information systems security, costs for smaller logistics companies, difficulties of implementation and interoperability problems. For example, one respondent suggested that forced adherence to generic rules was a barrier to using the Internet of things:

"*Linked to EU directives ... lack of general common sense and clarity from generic rules/laws applied in the UK*."

This probably refers to the need for international standards in data transfer protocols and other standards involved in the Internet of Things (Chaâri et al., 2016). However, one respondent with a good deal of experience of the freight transport industry gave a more balanced view suggesting there were opportunities and barriers to IoT use in the road freight transport industry:

“[The] *Internet of things has a place in helping freight operations become more sustainable, but until there are significant strides in 1) data standardisation on a supply chain level and 2) motivation of shippers to track the movements of goods upstream, these technologies will not proliferate across the supply chain*.”

Looking to the future, one respondent was clear that their company would ‘likely’ invest in IoT:

“*Going forward data* [is] *valuable in developing rail/road/drone networks*.”

Table 3. Barriers to Using the Internet of Things Technology

Barriers against Internet of Things technology (Literature Review)	**Barriers against Internet of Things technology (Pilot Survey Results)**
Privacy, Identity Management, Security and Access control (Li et al., 2016; Gilchrist, 2017; Welbourne et al., 2009)	Privacy, security and access issues were identified by respondents.
Standardisation issues and Interoperability (Coetzee and Eksteen, 2011)	Difficulties in standardisation
Data deluge (Miorandi et al., 2012, Lee and Lee, 2015)	Data deluge
Cost of purchase (Gilpin, et al., 2014; Liotta, et al., 2015; Cheung et al., 2008)	Initial purchase costs were of major concern to many respondents.
Implementation and maintenance costs (Gilpin, et al., 2014; Liotta, et al., 2015)	Cost of implementation, training and maintenance
Errors become more profound in a hyper connected world known as the “chaos challenge” (Lee and Lee, 2015)	Compatibility of devices and applications
Lack of IT knowledge (Oberhofer and Fürst, 2013; Richardson, 2005)	Lack of IT knowledge was of some concern
Unexpected safety and security issues - hackers (Li et al., 2016; Gilchrist, 2017; Lee and Lee, 2015)	Security, moral and ethical issues were mentioned but few respondents thought of security issues.

4. Conclusions

It is plainly evident from the pilot survey that the IoT has a pivotal role to play in securing the social, economic and environmental sustainability of freight transport. All of the respondents agreed that IoT technology has a role to play in the environmental and social sustainability of freight transport. There was a clear direction in the literature which was echoed very clearly by the respondents in this pilot survey questionnaire and is evidenced in tables 2 and 3 above.

A clear research gap exists in the literature of the IoT and road freight transport, which this research has begun to partially fill. However further research will have to be done to ascertain exactly how the IoT technology can drive the sector forwards and which technologies will have the most profound impact.

There is limited academic understanding on how the IoT and its technologies can be incorporated into business processes within the road freight transport industry. There are major barriers to both academic understanding and practical applications of these IoT technologies in the industry. Undoubtedly there is a potential for greater operational benefits but the barriers to implementation in smaller operators are high, mainly due to high cost and lack of expertise. It is also likely that these companies will be at most risk of data deluge and difficulties integrating various applications of IoT despite the benefits that they could bring.

This area of research is likely to be of interest to both academics and practitioners for the next few years as the awareness of these IoT technologies and the methods of integration become clearly and more widely understood, and that early adopters of these technologies demonstrate a clear competitive advantage. This affords an opportunity for freight transport operators to improve the sustainability of their operations, reduce costs (e.g. fuel costs), reduce emission of pollutants, reduce mileage, reduce vehicle and road wear and tear, reduce impact on congestion, and improve efficiency.

It is likely that for IoT to have a significant impact on the sustainability of transport operations, any transportation company considering adopting IoT technology would need to identify opportunities where they will be able to achieve a higher economic return from implementing the technology than the cost of its implementation. Therefore the cost of switching and implementation of IoT technology must not outweigh the expected economic returns, and furthermore there should also be a positive impact of switching to IoT technology on society as a whole (Macharis et al., 2014; Johansson, 2012; Hsu et al., 2015). Thus, in the first instance, businesses will likely decide which are the easiest and cheapest IoT technologies to implement and which will give them the greatest financial return.

Application of the Internet of Things (IoT) along with cloud-based Global Positioning Satellite (GPS) systems will bring about advanced visibility into the movement of products and will provide a platform for enhancing transparency and improving connectivity within freight transportation systems (Chaâri et al., 2016). This will result in a high degree of integration along the supply chain as IoT has the capability to connect every phase of freight transportation in real time. IoT and its enabling technologies can improve flexibility and responsiveness to sudden changes in the market environment, creating a significant source of competitive advantage (Hamilton, 1993; Kagermann et al., 2014), for example IoT can connect warehouse inventory, shipments, truck fleets and people to enable faster and more efficient operations in freight transportation activities (Sternberg and Andersson, 2014; Macaulay et al., 2015). Therefore, it could be argued that IoT can address the challenge of sustainability within the road freight transport industry by achieving significant economic gains, reducing fuel and energy consumption, and improving employee health and safety (Gecevska et al., 2012; Hsu et al., 2015). However, security issues have so far not been properly addressed (Li et al., 2016; Gilchrist, 2017). These issues of security present a significant barrier to IoT adoption and implementation that will perhaps be felt more keenly by SMEs with limited resources, and limited IT knowledge and experience.

4.1 Limitations and Further Research

The work presented here is in the early phase of the research process. The pilot survey questionnaire was limited to UK freight transport operators and not every aspect of the IoT was included in the study. It was intended to expand the IoT issues based on further literature and greater understanding of the technologies applied to the road freight transport industry.

In our view the IoT can improve the sustainability of road freight transport operations. However, this remains an emerging area of academic research and IoT technology is developing rapidly. The research presented in this paper is at an early stage and we intend to develop a full survey and supporting case studies to investigate the difficulties of implementing the IoT and improving the sustainability of road freight transport operations.

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