An Exploration of Supply Chain Visibility in the Life Science Industry

Dissertation submitted in part fulfilment of the requirements for the degree of

Master of Business Administration

Dublin Business School

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Declaration

I declare that this research is my original work and that it has never been presented to any institution or university for the award of Degree or Diploma. In addition, I have referenced correctly all literature and sources used in this work and this work is fully compliant with the Dublin Business School’s academic honesty policy.

Signed: ______________________

Date: ______________________
I would like to express my heartfelt appreciation to all of those who have supported me in my academic endeavours and to those who contributed to the successful completion of this research. I am very grateful for the time afforded to me by the busy supply chain practitioners who participated in the interviews and completed the questionnaires. Thanks also go to my employers and colleagues who have supported me throughout the MBA process and assisted me with the completion of the dissertation. I wish to thank my dissertation supervisor Mr. Dermot Boyle for his encouragement, guidance and insights. To my classmates, who have been a constant source of sound advice and humour in the face of adversity, I wish to extend both my thanks and congratulations. We did it! My parents and sister have provided me with a solid platform upon which to build my life and words of encouragement when the going was tough, for which I am ever grateful. Finally, there are few words which can adequately express the debt of gratitude I have towards my wife Dearbhla, and my sons, Finn and Culann, for their unwavering love, support and patience during the past two years as I undertook this MBA. Dad is finally finished his college thing! Yay!
Abstract

In an increasingly globalized world and competitive marketplace, the supply chains which transform raw materials into finished product are becoming more complex. This is especially true when it comes to the Life Science industry which has particular characteristics and challenges due to the value and sensitivity of the material being handled. The literature reveals that although supply chain visibility is viewed as a high priority for practitioners, it is often not clearly defined. This paper seeks to explore how practitioners in the life science industry view supply chain visibility, the challenges presented by their supply chains and the role that technology plays in addressing those challenges. The research strategy was to use mixed methods to collect data from practitioners in life science organisations and logistics service providers. A primarily inductive approach was used to analyse the collected data in order to identify common themes and sentiments. The findings of research broadly support the existing literature. Supply chain visibility is viewed as highly important in the life sciences industry. It appears that there may be a disconnect between the existence of large amounts of supply chain visibility data and the practical application of that data. The challenge of integrating data from various visibility systems persists and remains a barrier to achieving the levels of visibility that practitioners desire. Further research is recommended to explore the possible development of some standardization framework which may offer the industry an opportunity to capitalise on new technologies to deliver more coherent visibility systems.

Keywords

Supply Chain Management; Supply Chain Visibility; Internet of Things; Cloud Computing; Real-Time Location; Cold Chain Logistics
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<th>Description</th>
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<tr>
<td>Auto ID</td>
<td>Automatic Identification and Data Capture</td>
</tr>
<tr>
<td>EDI</td>
<td>Electronic Data Interchange</td>
</tr>
<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>LSP</td>
<td>Logistics Service Provider</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
</tr>
<tr>
<td>SCV</td>
<td>Supply Chain Visibility</td>
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<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
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</table>
Introduction

Overview

An important paradigm in the field of supply chain management is that of supply chain visibility. The topic of supply chain visibility is one which is mentioned frequently among practitioners, particularly among those who work for large companies with complex material flows or inventory configurations. Organisations operating within the life sciences usually have both. Supply chain visibility is often cited as a significant aspiration or concern among practitioners but as with many topics in the field of management there can be numerous interpretations of what supply chain visibility actually means. This research explores those interpretations. It also looks at some of the challenges faced by supply chain practitioners in relation to visibility and investigates ways in which technology can be used to address those challenges. In recent years the terms Internet of Things and cloud computing have become ubiquitous in technology circles. The technologies to which these terms refer are many, varied and have applications in several aspects of business and life. As supply chains become more complex it becomes more important for businesses to leverage the right technology to address challenges and improve visibility of their supply chain related activities.

Research Objectives

If the research were to be summarized into one overarching sentence, it might look like the following question, with the bullet points below outlining the objectives in finer detail.

What are the visibility challenges faced by supply chain practitioners for life science companies and can they be addressed using Internet of Things technologies?

- Examine the perception of what the term supply chain visibility means to supply chain practitioners.
- Identify the key supply chain visibility related challenges perceived by organisations.
  - Explore the possible barriers to achieving supply chain visibility.
  - Identify the supply chain visibility challenges with most financial impact.
- Explore the role technology plays in addressing supply chain challenges.
  - Explore the potential role of IoT technology in addressing those challenges.
  - Identify potential applications for improving cold chain logistics using IoT.
Rationale for the Research

Globalization and technology are significant factors which have led to increasing complexity in the nature of supply chains. The life science industry has characteristics which require specific attention to detail and accuracy. Ensuring patient safety relies on several specialized supply chain components functioning effectively, such as temperature sensitive products being handled in carefully controlled cold chain logistics infrastructure and consumables being produced and labelled in compliance with strict regulations and requirements such as batch level traceability. This backdrop makes it a particularly relevant industry when it comes to supply chain visibility, challenges and technology.

Almost all the world’s 25 largest life sciences companies have a footprint in Ireland, many with sizeable manufacturing plants and others with research and development operations. Those with manufacturing plants are typically importing raw materials and exporting finished product and the geographical location of Ireland presents unique and varied challenges. The researchers’ location and professional network presents an opportunity to collect relevant information about the perceptions of supply chain visibility and the nature of the challenges faced by these organisations in their supply chains. The research also looks at how the technologies of the Internet of Things are applicable to the mitigation of risk and loss reduction and how these technologies can be used to enhance the transparency of the product life cycle during the logistics and transportation phases of the supply chain. The research explores if the availability of real-time information can add value to businesses that are involved in moving product through the supply chain, either as product owners or as logistics service providers and investigates whether barriers, technological, organizational or inter-organizational, are perceived to exist which hamper the realisation of supply chain visibility.

The evolution of supply chain management is closely tied to the evolution of the technologies which support it. The continuing proliferation of the Internet of Things and cloud computing technologies and their possible applications in the supply chain, coupled with the researchers’ professional experience in the fields of auto-ID systems integration and supply chain visibility technology provide a solid foundation for undertaking a research project on this topic.

Researcher Background

The intersection of technology and supply chain visibility mirrors the areas of my own personal and professional interest. I have an honours degree in Computer Science and have spent my entire
professional career working in the area of supply chain technology. I have been employed for the past seven years by a company which provides supply chain visibility technology and services to customers across a range of industries including, but not limited to, life sciences, consumer electronics, food and beverage, logistics and transport. The company delivers these services by utilizing various hardware and software tools including cloud-based software platforms and Internet of Things hardware products, with a focus on temperature monitoring for cold chain logistics, security monitoring for high-value product in transit and logistics performance management. Previously I spent ten years working for a systems integration company specializing in auto-ID technology, barcoding and RFID.

**Potential Recipients for the Research**

The research may be of interest to people who work in the area of supply chain management, particularly those operating in the life sciences, such as pharmaceutical, biotechnology and medical device manufacturers. It may also be of interest to providers of logistics and distribution services such as warehousing and transportation to the life science manufacturers because of the particular sensitivities that are involved in the transportation of pharmaceutical product such as temperature and the threat of counterfeiting. Those working in information technology within those organisations may also be interested in the research. Service and technology providers to the life sciences particularly those involved in providing supply chain visibility software and hardware may also find the research useful.

**Structure of the Research**

The research is presented in the following format. The next chapter is a review of relevant academic literature on the topic of supply chain visibility and related technologies. The literature review is followed by a research methodology chapter which looks at the approach taken in the context of academic writing on research philosophy. In the subsequent chapters the results of the primary data collection and analysis are presented and discussed. The final chapter summarizes the conclusions and offers recommendations for further research.

**Contribution**

Despite the limitation of scope and resources, it is believed that the research provides supply chain practitioners working in the life science industry with useful insights into the shared experiences of
their colleagues. It is hoped that the paper will contribute to the growing body of knowledge forming on this important subject and provide researchers and academics with additional insights and perspectives. It is also hoped that the work will stimulate interest in further research into the subject.
Literature Review

Introduction

The review of the literature attempts to frame the research by looking at prominent writings on the subject of supply chain visibility, key concepts within the paradigm and perceptions of its meaning. A review of the supply chain, supply chain management and the evolution of associated technologies provides a context upon which the research attempts to build further understanding and depth.

Defining the Supply Chain

La Londe and Masters (1994, pp. 34-47) describe the supply chain as “a set of independent firms - raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies – involved in manufacturing a product and placing it in the hands of the end user.” Christopher (1992, p. 13) defines the supply chain as “the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer.”

Mentzer et al (2001, p. 4), having looked at a number of popular definitions propose the following, “a supply chain is defined as a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer.” They expanded this definition to encompass three levels of supply chain complexity shown below in Figure 1.

This definition acknowledges the role not only of the material and product producers but also, service providers and even providers of finance, demonstrating that supply chains have the potential to become very complex structures. Additionally, it is important to note that any one organisation can be a member of multiple supply chains simultaneously and in different capacities within each one (Mentzer et al. 2001). For example, an API manufacturer may be the consumer of another producers finished product in one supply chain, (purchasing material from a supplier to be used in the production of its own finished product) and be the supplier of a component in another supply chain (supplying active ingredient to a tablet producer) while also simultaneously being a customer of a third-party logistics supplier who provides warehousing and distribution services.
Figure 1. Three level of Supply chain complexity. (Mentzer et al., 2001)

Mentzer et al (2001, p. 4) are careful to separate the mere existence “of supply chains and the management of those supply chains. The former is simply something that exists, while the latter requires overt management efforts by the organizations within the supply chain.”

Supply Chain Management

The complex nature of supply chain configurations and their importance to business performance and organisational success has given rise to the very important business paradigm of supply chain management which is often regarded as a further evolution of logistics management. It is beyond the scope of this paper to explore in detail the myriad of concepts and theories around supply chain management, but it is important to at least identify a definition which captures the essence of the topic in a way that is relevant to the subject matter. As with other management topics, supply chain management has no one universally agreed definition but most describe the management (planning, control, coordination) of processes or activities within and between organizations involved in supply chains. Mentzer and his colleagues propose the following, “the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company, and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole” (Mentzer et al., 2001, p. 11).
Given that there is consensus that the supply chain is made up of interdependent organisations it could be argued that measures taken to improve the management of the activities carried out by these organisations should result in improved performance and thus deliver increased value to stakeholders. Holcomb et al (2011, p. 1) assert that sharing information in supply chains is the key to improved performance as information creates less uncertainty which in turn reduces the need to mitigate against risk. This was captured in the following statement. “The ability to “see” from one end to the other in the supply chain implies a clear view of upstream and downstream inventories, demand and supply conditions, and production and purchasing schedules.”

McIntire (2014) discusses how the ARA model views the supply chain as a set of Agents, Resources and Activities which can be optimised if the available sets of information each agent possesses are more closely aligned, citing "access to global information on the supply chain as a major driver for improved outcomes.” The consensus in the literature is that information access is essential for improved supply chain management, therefore, the application of technology to facilitating the capture, storage, processing and sharing of supply chain relevant information is central to successful supply chain management.

![ARA model proposed by the IMP Group (McIntire, 2014)](image)

Figure 2. The ARA model proposed by the IMP Group (McIntire, 2014)
Technology and Information Flows

Information technology offers opportunities to improve the information flows between supply chain actors. "Information technology also enhances supply chain efficiency by providing real-time information regarding product availability, inventory level, shipment status, and production requirements" (Radstaak and Ketelaar, 1998). Automated business-to-business (B2B) communication techniques can be implemented by organisations in order to automate the exchange of information or documents relating to supply chain activities or transactions. A prevalent form of automated B2B communication is known as Electronic Data Interchange (EDI) where business documents such as purchase orders and delivery documents are exchanged electronically between organisations. "The key idea of EDI is that the B2B communication takes place without human intervention" (Nurmilaakso, J.-M. 2003, p. 1). The absence of the requirement of human intervention is also an often-cited characteristic of the Internet of Things. The relevance of EDI and barcoding to supply chain activity is directly acknowledged, "Important improvements in barcoding and EDI lead to significant new potential for information exchange and coordination in the supply chains of apparel and food products" (McIntire, 2014; Hill and Scudder, 2001; Cooper, 2006).

The idea of data exchange without human intervention is a recurring theme that we will encounter in this literature review. Another theme which recurs is a lack of standardisation between technologies. This also applies to EDI as noted by Buxmann (2002, p. 2) who states that "Industry and nation-specific requirements on a business vocabulary have resulted in the development of many different incompatible EDI standards." In order to successfully achieve EDI, it is necessary to predefined the formatting of the messages which are exchanged in order for the systems to interpret and process them correctly. Extensible Markup Language (XML) is often utilized as a method of addressing the challenges of automated data exchange (Nurmilaakso, 2003, Buxmann et al., 2002, Zhou, 2015). Qiu et al. (2015) noted the qualities of ease-of deployment and flexibility of XML as a technology for supply chain data sharing. XML is one of a number of tools and standards which are used to facilitate the exchange of data between systems.

The importance of data sharing between supply chain actors is also emphasised by Jaradat et al. (2017, p. 10), "collaboration represents a culture of information-, planning-, risk-, and reward-sharing, among firms with similar attitudes towards the nature of the relationship that they share, and their unified efforts toward designing and adapting processes through which the participating firms may all prosper by more efficiently and effectively serving customers." It is evident from the
literature that information sharing is widely accepted as a means to enhance value throughout the supply chain. McIntire (2014) suggests that supply chain models of the 2000s had taken for granted that supply chains exist across organisational boundaries and that improved information access was a desirable goal of supply chain management theory. Barratt and Oke (2007, p. 2) suggest that “information sharing is an activity and that visibility is a potential outcome of such activity.”

Supply Chain Visibility

The term supply chain visibility is frequently mentioned as a priority for supply chain management professionals (Bradley, 2002; McCrea, 2005; Francis, 2008; McIntire, 2014). “Supply chain visibility can provide considerable advantages for organizations such as quick response, efficient customer service, forecasting capabilities, and replenishment capabilities” (Armistead and Mapes, 1993). McIntire (2014) alludes to the idea that there are two different perspectives with which supply chain visibility can be viewed. On the one hand it can be viewed as something which can be applied to a supply chain. (Company X has begun to implement a supply chain visibility project.) On the other hand, it can be viewed as a quality or a characteristic of a supply chain. (Company Y has a supply chain with a high degree of supply chain visibility.)

Francis (2008, p. 1) examined the use of the term “supply chain visibility” and found that even though “vendors, third party logistics providers, transportation and other companies profess to have or provide it, yet SCV remains one of the top issues consistently mentioned in surveys of supply chain management professionals.” Francis found that this was due in part to the lack of clarity around the meaning of the term and attempted to develop a coherent definition. The table below outlines a number of definitions taken from the literature.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bradley (2002)</td>
<td>“Capturing and analysing supply chain data that informs decision-making, mitigates risk, and improves processes”</td>
</tr>
<tr>
<td>Vitasak (2005)</td>
<td>“The ability to access or view pertinent data or information as it relates to logistics and the supply chain, regardless of the point in the supply chain where the data exists”</td>
</tr>
<tr>
<td>Kaipia and Hartiala (2006)</td>
<td>“The sharing of all relevant information between supply chain partners, also over echelons in the chain”</td>
</tr>
<tr>
<td>Barratt and Oke (2007)</td>
<td>“The extent to which actors within a supply chain have access to or share information which they consider as key or useful to their operations and which they consider will be of mutual benefit”</td>
</tr>
<tr>
<td>Francis (2008)</td>
<td>“The identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events”</td>
</tr>
<tr>
<td>Goh et al. (2009)</td>
<td>“The capability of a supply chain player to have access to or to provide the required timely information / knowledge about the entities involved in the supply chain from / to relevant supply chain partners for better decision support”</td>
</tr>
<tr>
<td>Klueber and O’Keefe (2013)</td>
<td>“Requisite supply chain visibility (RSCV) is the ability to provide and access information elements at a level chosen by the relevant supply chain stakeholders […]”</td>
</tr>
<tr>
<td>Heaney (2013)</td>
<td>“The awareness of, and control over, specific information related to product orders and physical shipments, including transport and logistics activities, and statuses of events and milestones that occur prior to and in-transit”</td>
</tr>
<tr>
<td>McIntire (2014)</td>
<td>“Supply chain visibility is a process of collecting supply chain data, integrating it, extracting intelligence from it and using that intelligence to interrupt decisions in a cross-organizational supply chain oriented context”</td>
</tr>
</tbody>
</table>

Table 1. Definitions of Supply Chain Visibility from the literature.
There is consensus that software vendors use the term “visibility” to describe differing supply chain technologies (Huddlestone, 2002; Briggs and Cecere 2003). This lack of clarity is acknowledged as a potential source of dissatisfaction or confusion when organisations implement a “visibility” solution which ultimately fails to deliver on the stakeholders’ expectation of what achieving visibility will actually mean. It is recognised by a number of authors that the diversity of, and disparity between the systems in use by the actors in supply chains presents a barrier to end to end visibility. This can be caused by the evolution of systems over time, “Because most systems have typically evolved over the years, often on a functional basis, various supply chain processes are disconnected” (Romano, cited in Holcomb et al, 2011). “This greatly hinders the ability of the firm and the supply chain as a whole to achieve end-to-end seamless visibility” (Holcomb et al., 2011, p. 33). Additionally, Jeyaraj and Sethi (2012, p. 21) found that “supply chain visibility may be impeded by the reliance on disparate home-grown systems, the selective automation of information sharing with only a few partners possibly due to mandates, and the implementation of different standards for information sharing by trading partners.” A 2017 IBM whitepaper suggests that “even organizations that have mastered visibility within their organization can’t see around all corners, particularly when goods are in transit” (IBM, 2017, p. 3).

Both Francis (2008) and Papert et al (2016) recognise the following entity attributes as being key to supply chain visibility - Identity, Location (or position) and Status. Papert et al (2016) assert that these attributes along with the availability of information about the attributes make up four dimensions of supply chain visibility.

<table>
<thead>
<tr>
<th>SCV dimension</th>
<th>Explanation</th>
</tr>
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<tbody>
<tr>
<td><strong>Availability</strong></td>
<td>Accessibility of information by all eligible supply chain actors&lt;br&gt;Availability demands information sharing</td>
</tr>
<tr>
<td><strong>Identity</strong></td>
<td>Provision of identity information&lt;br&gt;Level of detail depends on the demands of supply chain actors; and&lt;br&gt;Example: identity at object level or identity of a complete shipment</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td>Provision of position information about an object within the supply chain&lt;br&gt;Level of detail depends on the demands of supply chain actors; and&lt;br&gt;Example: GPS information about an object or information about which supply chain actor is currently responsible for which object</td>
</tr>
<tr>
<td><strong>Status quo</strong></td>
<td>Provision of information about the status quo of an object within the supply chain&lt;br&gt;Information can entail object- and environmental-related aspects; and&lt;br&gt;Example: information about transport, handling, storage, and temperature</td>
</tr>
</tbody>
</table>

Table 2. Dimensions of Supply Chain Visibility (Papert et al, 2016)
McIntire (2014) goes deeper into the subject of supply chain visibility and develops a theoretical framework aimed at addressing what he refers to as the three most significant barriers to building successful supply chain visibility solutions.

**Clarity around the definition** – The literature acknowledges that there are different perspectives on what exactly supply chain visibility is. McIntire puts forward the following definition, “Supply chain visibility is a process of collecting supply chain data, integrating it, extracting intelligence from it and using that intelligence to interrupt decisions in a cross-organizational supply chain oriented context” (McIntire, 2014).

**Prerequisites for successful implementation** – When it comes to implementing supply chain visibility solutions successfully, the literature points to three prerequisites - technological capability, organizational willingness and data quality (Hoffman and Hellström, 2008; McIntire, 2014).

![Supply chain visibility framework](image)

**Figure 3. Supply chain visibility framework (Hoffman and Hellström, 2008)**

**A mechanism for measurement** – Perhaps the most challenging factor in the implementation of supply chain visibility is being able to measure its success or otherwise. A commonly used approach “is to use existing models of overall business performance” (McIntire, 2014). McIntire (2014) points out that there is a difficulty with using overall business performance to measure the effectiveness of a supply chain visibility solution because business performance could be influenced by multiple other factors not associated with the supply chain visibility initiative. McIntire proposes a more granular methodology which he refers to as a “supply chain visibility scorecard” (See Appendix F). The scorecard is constructed around the four key factors in the definition proposed by McIntire - Data Capture, Data Integration, Intelligence Creation, Decision Interruption (McIntire, 2014).
McIntire (2014) identifies eight types of supply chain visibility and outlines industries to which they are particularly relevant. Below is a short summary of the description McIntire provides in relation to each visibility type.

**World as a Warehouse** refers to the ability to have a singular view of inventory status at and material flows between multiple different locations.

**Lot and Serial Number Tracking** describes the requirement to connect a product back to its origin via its historical data. Pharmaceuticals and food are examples of when it is necessary to have historical traceability.

**GPS Tracking** describes the use of GPS location and mobile computing to improve accuracy of supply chain activities and uses the example of a delivery driver or field service technician using the technology to ensure they are in the correct location.

**Inbound Track and Trace** describes the ability of organisations to view and forecast details of inbound product. This could include quantities product or arrival dates and can provide important decision making capabilities including staffing levels or storage constraints.

**Save the Sale** refers to the ability of a store to access inventory information from neighbouring or online outlets as a means to increase the chance that the customer will make a purchase.

**Competitive Market** visibility is having information about the supply chains of competitors. It can be seen as a useful tool for gaining or maintaining competitive advantage.
**Event Manager** describes visibility systems which monitor the status of supply chain entities such as quantities, shipments, dates and may include alarms or exception notifications allowing for improved planning and management capabilities.

**Status Visibility** is similar to event management in that both types require objects to have statuses, however status visibility would be considered a pre-cursor to event management with less decision making capability.

McIntire (2014) is careful to emphasise that the list of visibility types is not purported to be exhaustive. With the exception, perhaps, of save the sale, all of the above visibility types have applications for life science supply chain operations.

<table>
<thead>
<tr>
<th>SCV Type</th>
<th>Target Issue Addressed</th>
<th>Typical Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>World as a Warehouse</td>
<td>What is the total view of all inventory, regardless of location?</td>
<td>• Consumer products brands&lt;br&gt;• High Tech&lt;br&gt;• Pharmaceutical&lt;br&gt;• Heavy Manufacturing&lt;br&gt;• FMCG</td>
</tr>
<tr>
<td>Lot and Serial Number Tracking</td>
<td>What happened during the life cycle for a given product?</td>
<td>• High Tech&lt;br&gt;• Pharmaceutical&lt;br&gt;• Grocery and Food&lt;br&gt;• Chemical&lt;br&gt;• Spare parts and service&lt;br&gt;• Heavy Manufacturing&lt;br&gt;• FMCG</td>
</tr>
<tr>
<td>GPS Tracking</td>
<td>What is the right physical location?</td>
<td>• Logistics Service Providers&lt;br&gt;• Direct-to-customer&lt;br&gt;• Driver managed inventory&lt;br&gt;• Oil and Gas</td>
</tr>
<tr>
<td>Inbound Track and Trace</td>
<td>Will inbound product arrive on time?</td>
<td>• Retail, especially in the USA&lt;br&gt;• Heavy Manufacturing&lt;br&gt;• Oil and Gas</td>
</tr>
<tr>
<td>Save the Sale</td>
<td>Can the customer be promised something?</td>
<td>• Retail&lt;br&gt;• E-commerce retailers</td>
</tr>
<tr>
<td>Competitive Market</td>
<td>What is happening in my competitors supply chain?</td>
<td>• Consumer products brands&lt;br&gt;• High Tech</td>
</tr>
<tr>
<td>Event Management</td>
<td>Given a pattern of facts which I think is important, what actions should be taken?</td>
<td>• Consumer products brands&lt;br&gt;• High Tech&lt;br&gt;• Pharmaceutical&lt;br&gt;• Retail&lt;br&gt;• FMCG</td>
</tr>
<tr>
<td>Status Visibility</td>
<td>Given all the supply chain activity, is a given object in its expected status?</td>
<td>• Consumer products brands&lt;br&gt;• Retail</td>
</tr>
</tbody>
</table>

Table 3. Summary of Supply Chain Visibility Types (McIntire, 2014)
Supply Chain Entities

Francis (2008) describes the objects moving through the supply chain as entities. He organises these entities into a hierarchy from an item (product) up to a vehicle transporting that item.

“This hierarchy implies that items are contained in packages; one or more packages constitute a customer’s order; orders are encased in pallets, totes, returnable plastic containers or other form of encasement; encasements are often loaded into lading assets (container, trailer or ULD); lading assets are transported by vehicles (truck, train, ocean vessel, or aircraft)” (Francis, 2008, p. 182).

For each entity in the hierarchy is suggested a unique identifier, such as a product code, pallet number or container ID. The allocation of a unique identifier to each entity in the hierarchy, allows for information about its position and status to be recorded against that entity.

![Supply Chain Entity Hierarchy](image)

Figure 5. Supply Chain Entity Hierarchy (Francis, 2008)

The next sections of the literature review briefly outline Auto ID technologies which are widely employed in supply chain visibility and Internet of Things although less widely used, is beginning to become more prevalent. The final section of this paper will propose an alignment of the entities with appropriate technologies that can be used for tracking their progress through the supply chain.
**Auto ID**

The origin of the term “internet of things” is often accredited to Kevin Ashton, Executive Director of Auto-ID Labs in MIT in 1999 (Madakam et al., 2015). Technologies such as barcodes and radio frequency identification (RFID) come under the umbrella term Automatic Identification and Data Capture (often abbreviated as Auto ID) and refer to methods of storing and/or collecting data about an object and entering it into a computer system. These technologies have for many years been utilized in systems and processes associated with supply chains and supply chain management (McIntire, 2014; Hill and Scudder, 2001; Cooper, 2006). Barcodes are machine readable printed codes which can store a string of alphanumeric characters which can be used to encode product identification codes or other information. They are widely used in retail and warehousing.

Barcodes are ubiquitous but have some limitations. The amount of information which they can store is relatively small. They lack the ability to write additional information to the code. “Conventional [1D] barcodes can only hold a small amount of information, typically around 20 characters, and can’t be reprogrammed” (d'Hont, S., 2004, p. 3). They also require line of sight to the scanning equipment in order to be read and can only be read from distances ranging from a few centimetres to a few meters.

The development of 2D barcodes addressed the data storage limitation to a certain degree by enabling “a large amount of data [to] be encoded in a small space, with the capacity to hold up to 3116 numeric digits, 2334 alphanumeric characters or 1556 8-bit ASCII characters” (IEEE, 2005). A further limitation is acknowledged by Papert et al. (2016, p. 865) who note that “the barcode cannot prevent counterfeit products from entering the supply chain.”

The development of RFID went some way toward addressing some of the limitations of barcodes in that it eliminates the requirement for line of sight, provides the ability to write new information to the tag and has a high data storage capacity. “The most prominent feature of RFID technology is: non-contact reading and writing, distance from a few cm to dozens of meters” (Chen, X.-Y. and Jin, Z.-G. 2012, p. 562). In addressing these limitations, RFID technology is typically more expensive than barcode technology and has been identified as a barrier to the adoption on the technology (Akad Colak, 2014).

RFID tags come in two basic types, passive and active. Passive tags do not have an internal power source and use the electromagnetic field generated by the reading antenna to induce the power
required to transmit. The read range on passive tags is typically between 10 centimetres and 2 meters. Active tags contain a battery and thus typically have a longer reading range. A common use case for active tags is for automated identification of vehicle moving through toll-plazas. Active tags typically have a range of between 1 and 100 meters (Glover and Bhatt, 2009).

The advent of RFID was seen by some as signalling the end of the barcode. “RFID promises to replace the old barcode and contributes to the real time visibility of the goods, regardless of the location of the supply chain” (Sun, 2012, p. 107). The reality however is that the higher cost and infrastructure requirements have prevented RFID from achieving the ubiquity of the barcode. In relation to real-time supply chain visibility, there is a further impediment. For both RFID and barcode systems, it is required for there to be scanning or reading infrastructure present in order to transfer the information stored in the code or the tag into a computer system. This infrastructure is typically in the form of automated fixed mount scanning arrays or handheld scanning devices which require human activation. This dictates that the reading of information can only occur at locations where this infrastructure exists. During the transit of product through the supply chain, these locations are likely to include manufacturing plants, distribution centres, logistics providers, transport hubs and delivery points.

RFID has many different standards and protocols, which means that any RFID infrastructure present at a particular location may not be capable of reading the particular type of tags which are transiting that location. This lack of standardization is another barrier to widespread RFID adoption as noted by Adhiarna and Rho (2009, p. 1466) who state “Standardization remains a complex issue for RFID worldwide adoption, and both general standards as well as industry-specific standards are needed.”

Despite the challenges, the technologies of Auto ID are widely used as enablers for supply chain visibility. They can be viewed as pre-curors to the Internet of Things and the technologies of IoT have the capability to overcome some of the limitations of Auto ID which can be applied to further enhance supply chain visibility.

**Internet of Things**

*Internet of Things* is a collective term for the myriad of devices and sensors which collect and exchange data. IoT broadly references the proliferation of wireless sensor networks - interconnected devices which autonomously collect and exchange data, without the requirement
for human intervention, via their connection to the internet. IoT encompasses the previously used term machine-to-machine communication (M2M) which the European Telecommunications Standards Institute defined as “the communication between two or more entities that do not necessarily need any direct human intervention. M2M services intend to automate decision and communication processes” (European Telecommunications Standards Institute, 2010). IoT also incorporates machine-to-human communication (M2H) by which “humans are able to gather and analyse data from devices, as well as receive email and text alerts from IP enabled “things” when certain predefined conditions are met” (L-com, 2016).

The proliferation of IoT in recent years can be linked to some key technological developments. The growing availability of wireless communications networks, such as wi-fi and cellular and the increasing number of wireless enabled devices enables the transmission of data from an increasing geographical area (Gubbi et al., 2013). Additionally, the development of IPv6 facilitates the allocation of unique communications addresses to billions of devices and improvements in battery technology are increasing the autonomy of devices (Kumar et al., 2016). The growing paradigm of cloud computing also facilitates the processing and sharing of information collected by IoT devices.

A significant contributor to the growing Internet of Things is a range of technologies which come under the umbrella term Wireless Sensor Networks (WSN). WSNs are defined as “self-organizing, multi-hop networks of wireless sensor nodes used to monitor and control physical phenomena” (International Electrotechnical Commission, 2014). There are many applications for the data that is collected by the array of Wireless Sensor Networks which contribute to the IoT.

Some examples are described in a 2014 IEC whitepaper. Car parking space availability monitored by sensors and displayed on information screens on approach roads. Traffic monitoring sensors provide real-time data to route planning systems and warning signs on motorways. Public transport vehicles send real-time location information which passengers can access on smartphones. Weather sensors provide real-time weather conditions and forecasts. Street lighting is controlled by ambient light detectors to optimize effectiveness while conserving energy. Environmental sensors can be configured to detect vibrations or heat to forewarn of forest fires, avalanches, earthquakes and tsunamis. (International Electrotechnical Commission, 2014).

“Analysts have predicted that the installed base for Internet of Things devices will grow from around 10 billion connected devices today to as many as 30 billion devices by 2020” (Bauer et al, 2014). This growing paradigm also encompasses industry and supply chain application as noted by
Zhou (2015, p. 1), “Applications of IoT are taking place in sectors such as transportation, energy, healthcare, pharmaceuticals, retail, manufacturing product lifecycle management, recycling and food traceability.”

**Cloud Computing**

Cisco predicted that by 2020 there would be approximately 15 zettabytes (or 15 trillion gigabytes) of digital data in cloud data centres by 2020 (Cisco, 2015). There are broad academic and technical debates about the precise definitions and characteristics of cloud computing and where the demarcation lines between cloud and other types of distributed systems exist. For example, according to National Institute of Standards and Technology (NIST), "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (National Institute of Standards and Technology, 2011). That debate is beyond the scope of this work, but it is important to acknowledge the role of cloud based systems in supply chain related information technology systems (Guo et al., 2015). Supply chains as collaborative networks of information and product flows can benefit from the availability of relevant information to the many actors when required.

**Cold Chain Logistics**

Of particular relevance to some life science companies is the subject of cold chain logistics. This refers to the supply chain processes involved in the manufacture and distribution of temperature sensitive product such as food, chemicals and pharmaceuticals. The cold chain includes environmentally controlled storage facilities, specialized packaging materials, and environmentally controlled vehicles or transportation units. Managing and maintaining the cold chain requires active participation from the various parties involved in handling the product. If we take the example of temperature sensitive pharmaceutical product life cycle, there are various stages including manufacture, warehousing and distribution. At each of these stages there must be controls in place to ensure that the product is always maintained within the required temperature range. Manufacturing plants will have temperature-controlled environments and monitoring equipment in place. Logistics providers will have similar environments at their warehousing facilities. The vehicles and transportation units used to transport the product will be similarly controlled. A challenge faced by the industry is that quite often the equipment and systems in place
at each of the stages of the supply chain are separate entities owned by various stakeholders with various interests (Jeyaraj and Sethi, 2013; Holcomb et al., 2011). This means that the temperature history of the product is often disjointed and stored on multiple systems accessible by specific supply chain actors.

The use of small, battery operated data loggers bridges the gaps at those challenging points of the supply chain where the product passes from one controlled environment to another by accompanying the product and recording the temperature at set intervals. "Electronic temperature data loggers provide valuable information in a convenient format. This includes documentation of temperature and humidity including time and date as well as specific identification" (Ames, 2006, cited in Bishara, 2006, p. 3). The data loggers are checked at the point of delivery to ensure that no temperature excursions have taken place during the shipment duration. While this is an effective way to address the issue of continuity between systems, it has the disadvantage of highlighting the problem only after it has occurred, and at which point it may be too late to prevent product spoilage.

**Conclusion**

The literature presents supply chains as potentially complex interorganisational arrangements. Collaboration and sharing of information are generally accepted as desirable characteristics of effective and efficient supply chains. There is consensus also that supply chain visibility is an important component of effective supply chain management. It is widely acknowledged that information technology is an important tool for delivering supply chain visibility. It is also evident that the systems upon which organisations rely for supply chain visibility are numerous and often disconnected and that this lack of connectivity presents challenges to achieving the levels of visibility which are seen as desirable by practitioners. The research attempts to explore this subject specifically in relation to the life science industry by collecting data from practitioners through interviews and questionnaires. The next chapter describes in detail the research methodology used.
Research Methodology

Introduction

When conducting any research, it is important for the researcher to demonstrate a sound understanding of the area of research methodology to frame the research against an informed methodological perspective. In writing about philosophical issues of such depth and complexity it is also necessary to accept the limitations of the scope of such a paper, which dictates the necessity to summarize complex topics and to accept that the resulting summarizations may be incomplete.

Management research has some perspectives and challenges which should be looked at to gain an informed basis upon which to make decisions around the research methodology to be undertaken. At the centre of the discussion are the academic disciplines of natural science, which includes physics, chemistry and biology; and social science which includes psychology, economics, law and anthropology. Much of the literature aligns natural science with the philosophy of positivism; and social sciences with that of interpretivism which will be addressed in following sections.

Bell and Thorpe (2013, p. 1) point out that the application of scientific method to management research can be compared “to bureaucracy and the notion of goal displacement.” The suggestion is that by adhering too closely to procedure, there is a potential that the original aims of the endeavour become lost and may be replaced by other objectives, which in some cases simply serve to justify the ongoing existence of the bureaucracy. Gill and Johnson (2010, p. 4) discuss a diversity which exists in management research in part “because of its position at the confluence of numerous social science disciplines (e.g. sociology, psychology, economics, politics, accounting, finance and so on).”

One of the more broadly accepted models of research which attempts to map the research philosophy with the approach, strategy and methodology is the ‘research onion’ (Saunders et al, 2003). This model is popular and often referenced but as noted by Knox (2004) there is a potential for researchers and students to apply the model too rigidly and ignore certain approaches or methodologies depending on how they are linked in the model. For example, the prevailing interpretation is that positivist philosophy dictates a deductive approach which in turn dictates quantitative data collection. (The converse of this being that interpretivist dictates induction and therefore qualitative methods.) This is not to say that Saunders et al have drawn a definitive line in their model, but it is a thread which is evident in much of the literature.
Crotty (1998) suggests that when embarking on a research project, there are two initial questions – What methodologies and methods will be used? How do we justify this choice? He puts forward the idea that the justification of the choice of methods “reaches into [the researchers] assumptions about reality” - their theoretical perspective. This in turn leads to questioning the nature of knowledge, epistemology. According to Crotty, the initial two questions then become four.

1. What methods do we propose to use?
2. What methodology governs our choice and use of methods?
3. What theoretical perspective lies behind the methodology in question?
4. What epistemology informs this theoretical perspective?

The model which Crotty proposes differs from that of Saunders et al, in that “the distinction between qualitative and quantitative research occurs at the level of methods [and] not at the level of epistemology or theoretical perspective” (Crotty, 1998, p. 15). Crotty makes the point that while the epistemology of positivism is at the opposite end of the spectrum to interpretivism, many research textbooks make a similar assertion about quantitative and qualitative methodology which he argues is not the case. It is in line with the four elements model of Crotty that this research was approached.

The research was approached using the Hutter–Hennink qualitative research cycle model which outlines a three-phase approach to qualitative data analysis. The design phase, during which the literature review aids in the development of themes, related to the research objectives which can be explored in the qualitative data collection. The ethnographic cycle involves the design of the data collection instruments, the identification of the research population and the data capture. The
analysis cycle consists of the interpretation and coding of the collected data. It also links back to the design cycle by attempting to align the conceptual frameworks with theory development (Hennink, Hutter and Bailey, 2010).

![Figure 7. The Hutter–Hennink qualitative research cycle model (Hutter, Hennink & Bailey, 2010)](image)

**Research Philosophy – Ontology and Epistemology**

It is important to define two commonly used terms which recur in discussions about research philosophy – ontology and epistemology. Ontology is concerned with the nature of existence or being and is generally divided between objectivism and subjectivism. Subjectivism is sometimes also referred to as constructionism, although constructionism is regarded as an epistemological stance (Morgan, 2007). Objectivism is defined as “an ontological position that asserts that social phenomena and their meanings have an existence that is independent of social actors.” Constructionism asserts that “social phenomena and their meanings are continually being accomplished by social actors” (Bryman and Bell, 2011, p. 22).

Epistemology is concerned with the nature of knowledge. Maynard (1994, p. 10) says that epistemology is “concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate”. For the purposes of this paper we will look at four broad categories of epistemology – positivism, realism, interpretivism and pragmatism.
**Positivism**

Positivism is an “epistemological position that advocates the application of the methods of the natural sciences to the study of social reality and beyond” (Bryman & Bell, 2011, p. 16). According to Bell and Thorpe (2013) the positivist approach to research is to collect data through empirical observation to generate theory which explains why things are the way they are. According to Creswell (2013) post-positivism “represents the thinking after positivism, challenging the traditional notion of the absolute truth of knowledge and recognizing that we cannot be positive about our claims of knowledge when studying the behaviour and actions of humans” (Creswell, 2013; Phillips & Burbules, 2000).

**Realism**

Philosophical realism has been defined as “the view that entities exist independently of being perceived or independently of our theories about them” (Phillips, 1987, p. 205). This definition is applicable also to the term empirical realism which according to Bryman and Bell (2011) asserts that through the use of appropriate methods, reality can be understood. This is somewhat aligned with positivism and as noted by Bhaskar (1989, p. 2) “fails to recognise that there are enduring structures and generative mechanisms underlying and producing observable phenomena and events” and is therefore “superficial”. While positivism asserts that reality observed is knowable, critical realism accepts that conceptualizing reality is simply a way of knowing that reality.

According to Maxwell (citing others, 2012, pp. 3-4), realism has been the dominant philosophical approach in social sciences for over 30 years, (Baer, 1998; Hammersley, 1998). Maxwell outlines several variations of realism, such as “experiential” realism (Lakoff, 1987), “constructive” (and, later, “perspectival”) realism (Giere, 1999), “subtle” realism (Hammersley, 1992a) and “emergent” realism (Henry, Julnes, & Mark, 1998)” which he groups together as critical realism. What they have in common, he says “is that they deny that we can have any “objective” or certain knowledge of the world and accept the possibility of alternative valid accounts of any phenomenon” (Maxwell, 2012, p. 5). Critical realism is more aligned to interpretivism in that it accepts that events and discourses can be understood by identifying “the structures at work that generate those events and discourses” (Bhaskar, 1989, p. 2).

**Interpretivism**

Interpretivism is closely linked to social constructionism because it follows from constructivist ontology. It differs from positivism in that it sees social reality as intrinsically linked to the social
actors of which it is comprised, whereas positivism views social reality as existing objectively (Bell and Thorpe, 2013). Interpretivism “is predicated upon the view that a strategy is required that respects the differences between people and the objects of the natural sciences and therefore requires the social scientist to grasp the subjective meaning of social action” (Bryman & Bell, 2011, p. 19). Interpretivist research is concerned with understanding the way in which humans interpret the social reality in which they operate. The interpretivist researcher is cognizant of their own perspective and how that may shape their interpretations of the information they collect (Creswell, 2013). Crotty (1998) explains that according to constructivism, meaning is not discovered in objects but is constructed by people interacting with them.

**Pragmatism**

According to Bernstein (1992), pragmatism as a philosophical worldview has its origins in the works of C.S Peirce (1839-1914), William James (1842-1910) and John Dewey (1859-1952). Bernstein describes how following the death of Dewey, pragmatism fell out of favour, but has enjoyed resurgence in recent years. He describes the common view held by the “classical” pragmatists as questioning the idea “that philosophy or inquiry rest on secure, fixed foundations which can be known with certainty.” (Bernstein, 1992, p. 814-5). Instead reality is viewed as constantly changing, under construction and reconstruction.

It can be argued that, while positivism holds what Mutch (2004) describes as an "elective affinity" to quantitative research method, and interpretivism holds an “elective affinity” to qualitative research methods; pragmatism holds an elective affinity to the use of mixed methods in research, because it “sidesteps the contentious issues of truth and reality, accepts, philosophically, that there are singular and multiple realities that are open to empirical inquiry and orients itself toward solving practical problems in the “real world” (Feilzer, 2010, p. 8; Creswell & Plano Clark, 2007, pp. 20-28; Rorty, 1999). Critics of pragmatism, including Bertrand Russell, assert that because it advocates a “what works” approach to research methods, pragmatism tends toward apportioning truth based on the researchers’ interpretation of the results.

The research philosophy layer of the research onion model developed by Saunders et al, aligns approximately with both the theoretical perspective and epistemology of the Crotty model, as he argues that “to talk about the construction of meaning [epistemology] is to talk of the construction of a meaningful reality [ontology]” (Crotty, 1998, p. 10). The epistemological position of the researcher is in alignment with constructionism which posits that the nature of reality in social
organisation is something which is undergoing constant change, influenced by the actors and activities involved and therefore the epistemological underpinning of my research is from the interpretivist and pragmatist perspective.

**Research Approach**

The often-cited ‘research onion’ (Saunders et al, 2003) positions the research approach layer below the research philosophy layer, which we have shown to contain epistemological standings. In this model, we find deductive and inductive approaches, aligned with positivism and interpretivism respectively. The deductive approach associated with the positivist tradition consists of generating hypotheses based on existing knowledge and then testing the hypotheses using empirical observation (Bell and Thorpe, 2013). With the inductive approach, the researcher uses interpretation of the research data to generate theory. This was captured very succinctly by Bryman and Bell (2011, p. 4), who in summarizing an exploration of the relationship between theory and research ask; whether theory guides research (deductive approach) or whether theory is the outcome of research (inductive approach). Supporters of the mixed methods approach advocate a third approach known as abductive. This refers to an iterative or cyclical approach where researchers “move back and forth between induction and deduction – first converting observations into theories and then assessing those theories through action” (Morgan, 2007, p. 71).

![Deduction v Induction](image)

*Figure 8. Deduction v Induction (Gill and Johnson, 2010)*

**Deductive Approach**

With the deductive approach, it is necessary for the researcher to take hypotheses into the research which specify a causal relationship between variables. The research, through empirical observation,
will then either support or refute the hypotheses (Gill and Johnson, 2010). Supporters of this approach assert that because it takes a positivist approach like that of the natural sciences, its findings “are therefore pivotal to promoting organizational effectiveness and efficiency by providing verified guides to managers’ interventions into their organizations” (Hogan and Sinclair, 1996, cited in Gill and Johnson, 2010, p. 13). Gill and Johnson (2010) argue that inherent meaning and cultural subjectivity of human behaviour may render the methods of the natural sciences inappropriate for management research.

**Inductive Approach**

The inductive approach involves the implementation of a data collection process, after which the data is analysed to identify the emergence of patterns or themes out of which generalizations or even theories may be generated. Gray (2004) is careful to point out that induction does not preclude or ignore pre-existing theory. With induction, the general sequence is collection of data followed by generation of theory. “The process of induction involves drawing generalizable inferences out of observations” (Bryman and Bell, 2011, p. 14). Bryman and Bell (2004) also point out that in some cases the outcome of the research is not theory but “empirical generalizations”. Critics of the inductive approach and of interpretivism can use this to argue for more positivist or realist approaches.

**Abductive Approach**

An approach popular in pragmatist philosophy is known as abduction. Abduction is seen as an iterative or cyclical process during which data is collected, generalizations are made, theory is developed, further data is collected, etc. Abduction has also been described as “uncovering and relying on the best of a set of explanations for understanding one’s results” (deWaal, 2001; cited in Johnson and Onwuegbuzie, 2004, p. 17).

A criticism of abduction, like that given to pragmatism and grounded theory could be attributed to a certain lack of conviction about the results. This was captured by Reichertz (2010, p. 9) saying “faced with surprising facts, abduction leads us to look for meaning-creating rules, for a possibly valid or fitting explanation that eliminates what is surprising about the facts”. Morgan (2007, p.71) discusses “a particular version of the abductive process... where the inductive results from a qualitative approach can serve as inputs to the deductive goals of a quantitative approach, and vice versa.”
While the research approach undertaken was primarily inductive consisting of data collection through interviews, data analysis, data coding and theme identification, an abductive process was also utilised by using an initial analysis of the collected interview data to inform and support the design of the structured questionnaire for further data collection.

**Research Strategy**

Research strategy broadly refers to the methodology which is used to collect the data. Examples of research strategies are survey, experiment, grounded theory and ethnography. The strategies tend to be classified as either qualitative or quantitative. As previously mentioned, the ‘research onion’ (Saunders et al, 2003) tends to more closely align positivism with quantitative research methods and interpretivism more closely with qualitative research methods. Creswell (2013) suggests that it is appropriate to say that in general research tends towards being either more qualitative or more quantitative.

Mutch (2004) suggests the idea of elective affinity, whereby a philosophical standpoint may suggest the methodology and approach but does not preclude the researcher from utilizing “what is best, from the myriad of tools available, for a particular piece of research” (Mutch, 2004; Knox, 2004, p. 124). This idea of elective affinity is closely in line with the approach described by Crotty. The use of mixed methods is also supported by Johnson and Onwuegbuzie (2004, p. 16) who propose that “Mixed methods research should [...] use a method and philosophy that attempt to fit together the insights provided by qualitative and quantitative research into a workable solution”. Silverman (2013, p. 9) notes “rather than one methodology being intrinsically superior to another, it might be wiser to think of quantitative and qualitative approaches as complementary parts of the systematic, empirical search for knowledge.”

The strategy taken for this research is pluralistic, including both interviews and a questionnaire which attempt to build qualitative data from supply chain management professionals. The interviews attempt to gain insight into the perspective of supply chain practitioners in life science companies as to the meaning of the term supply chain visibility. They aim to identify the main challenges in supply chain management faced by these organisations and to explore how technologies are being used applied to addressing those challenges. The interviews seek to identify recurring themes that may inform grounded theory and help guide the development of the questionnaire which will seek to further probe the emerging themes. The use of the questionnaire is seen as a way to support the qualitative research and not as method of collecting data for
quantitative analysis. The survey will allow the development of a more informed picture by focussing on topics already emerging from the interviews.

Population and Sample

When it comes to the collection of data, population and sample are two important terms. Broadly speaking, the population can be viewed as the entire set of people about which the research aims to make generalizations. The sample is the subset of the population which are selected to participate in the research.

Zikmund (2000) describes a method of defining the target population by asking questions about the characteristics of that population. For example, ”Whom do we want to talk to?” In the case of my research, the answer to this question is: People employed by life science companies who are knowledgeable in the area of supply chain management.

The people who fit into this description are difficult to identify as they could come under many different job titles or hold positions in various departments such as logistics, transport, information technology, quality assurance, security, finance, etc. This makes it difficult to accurately identify the entire target population and thus rules out taking a census. “A census is an investigation of all the individual elements that make up the population—a total enumeration rather than a sample” (Zikmund, 2000, p. 387). When a census is not possible, techniques known as sampling must be
employed. Sampling involves selecting a subset of the entire population and using the data captured from that subset to infer generalizations about that population.

While surveying of populations or samples tends to be the favoured method for collection of numeric, statistical, quantitative data; that is not necessarily always the case as noted by Fowler (2009, p. 14) who states, “There are occasions when the goal of information gathering is not to generate statistics about a population but to describe a set of people in a more general way.” Crotty (1998) suggests that the data collection methodology should be determined by identifying the nature of the data we wish to collect. The research seeks to identify trends in the perceptions of people working in supply chain related roles. As already established in the literature review, the supply chain can have a wide range of influence across organizations. Since the target population are a group of people with knowledge or professional experience of a certain topic, the type of sampling being used is categorized as nonprobability sampling.

**Probability and Non-probability Sampling**

There are two broad categories of sampling – probability and non-probability. Zikmund (2000, p 395) defines probability sampling as follows, “In probability sampling, every element in the population has a known, nonzero probability of selection” whereas “in nonprobability sampling, the probability of any particular member of the population being chosen is unknown”. Put simply, nonprobability sampling occurs when the selection of the sample units is based on judgement or convenience.

Judgement sampling is a type of nonprobability sampling in which an experienced individual selects the sample “based on personal judgement about an appropriate characteristic of the sample member” (Zikmund, 2000, p. 396). Another technique known as snowball sampling occurs when “additional respondents [are acquired] through information provided by the initial respondents” (Zikmund, 2000, p. 398). With this in mind I have employed a combination of judgement and snowball sampling in my research. In order to capture units of the target population in the research, I used professional contacts to either directly identify interview candidates or to identify relevant persons who themselves would have knowledge of other persons in the organisation that possess the required characteristics. It is acknowledged that this technique introduces a risk of bias since those respondents suggested by the initial respondents are likely to have similarities in their experiences of the subject matter due to their association with one another.
Through my current role in supply chain visibility service provision and my previous roles in auto-ID systems integration, I have a network of contacts in a broad range disciplines associated with supply chain management, including logistics, security, transport, pharmaceutical quality control, compliance and systems integration. I had initially thought that I could utilize this network for the purposes of identifying and selecting all the interview candidates for my research, however, in deciding to narrow the focus of my research to the life science industry, I had to re-evaluate that approach and needed to leverage the contacts of some colleagues; snowball sampling. I accept that there is a risk of a level of influence being exerted on the data collection by virtue of the fact that the interview candidates are familiar with the company I am employed by. The familiarity may cause discussion topics to drift towards subjects which are related to the fields in which my organisation operates. During the data analysis I am cognizant of these issues and attempt to take potential biases into account.

**Data Collection Instruments**

**Interview Design**

Interviews are a popular method of collecting qualitative data and are used extensively in the social sciences and research about business and management. Broadly speaking there are three types of interviews commonly used in qualitative research; structured, semi-structured and unstructured. Structured interviews have fixed questions and may provide specific answers for the interview to select from. Semi-structured interviews have fixed questions which will be asked but are also flexible so that other questions or topics which arise during the interview can be answered or explored. Unstructured interviews are more conversational and informal where no predetermined questions are asked.

The interviews conducted were semi-structured in nature with predefined questions which were written with the aim of exploring the research objectives and were open-ended to allow the respondent to elaborate as desired.

**Questionnaire Design**

“A questionnaire is a formalized set of questions for obtaining information from respondents” (Malhotra, 2006, p. 176). The online questionnaire was viewed as an appropriate way to collect additional qualitative data to augment the data collected through interview. Due to time constraints it was decided that the questionnaire should be built and distributed quickly to maximize the
exposure time to the potential respondents. To achieve this, a preliminary analysis took place on the interview data to inform the questionnaire design. Broadly the themes were consistent with those of the interviews, but there were some themes which emerged during the interviews which merited further exploration. The questionnaire also afforded the opportunity to examine sentiment in relation to certain topics by utilizing scales. Malhotra (2006) describes a set of guidelines to assist in the development of a questionnaire which is summarized below. The questionnaire was designed using these guidelines.

**What Information Is Needed?** – The questionnaire should be designed in a way that supports the capture of the required data.

**How Should Individual Questions Be Framed?** – It should be determined if the question is necessary or superfluous or if multiple questions are required to answer the question.

**Are the Respondents Able to Answer the Question?** – The respondent may not be informed about the question topic or may not have access to the information. The questions were designed in a way which attempted to limit this. In cases where it was considered a risk, options such as “Unsure”, Not applicable” or “Other” were included.

**Are the Respondents Willing to Answer the Question?** – Respondents may decide not to answer a question if it is deemed too personal or requires too much effort to answer. Questionnaire design should be cognizant of this.

**What Should Be the Structure of the Question?** – Questions can be either structured or unstructured. Unstructured questions allow respondents to express opinions or attitudes in their own words and in general are useful in exploratory research. Structured questions specify a limited number of possible responses by offering respondents multiple-choices or scales. In designing multiple-choice questions there are two important considerations - “The alternatives should be mutually exclusive and collectively exhaustive” and position bias or “the respondents’ tendency to check an alternative merely because it occupies a certain position in a list.” The researcher was cognizant of position bias in the analysis of the scale questions and, where possible, used position shuffling; an electronic function available in the survey software which automatically randomized the order in which alternatives for multiple-choice questions were displayed.
What Type of Scales Should Be Used? – Scales allow for respondents to select an option which most appropriately describes their attitude or reaction to a statement. The Likert scale is one of the most popular types of scale used in questionnaire design and was selected for use in the work.

How Should the Question Be Worded? – Poorly worded questions can lead to confusion or misinterpretation, so care must be taken in the choice of words. Ordinary, unambiguous language should be used, and leading or biasing questions should be avoided.

What Is the Proper Order of Questions? – Consideration should be given to the order of the questions. Questions may be ordered in thematic groups and shift from general at the beginning to more specific towards the end. Questions which are more difficult to answer may be left until the end at which point the subject matter may be more clearly understood and the respondent has already committed to participation.

How Should the Questionnaire Be Pretested? – In order to test and improve the flow of a questionnaire, it should be given to a test group, ideally with similar characteristics to the target group. The questionnaire was distributed to a group of the researchers’ colleagues in advance of distribution for this purpose.

The steps outlined above are based on “Questionnaire Design and Scale Development” by Malhotra (2006, pp. 176-195).

Data Analysis and Coding

Once the data had been collected and transcribed, the researcher began the process of data analysis and coding. Coding is a process during which qualitative content is analysed and classified into categories and related groups and themes present in the data are identified. Themes fall into two categories, priori themes which are present in advance of the data collection and emergent themes which become evident during the data collection and analysis processes.

Zhang and Wildemuth (2009, pp. 3-5) describe a process of data analysis and coding which is summarized below. The research was analysis and coded using this process.

1. Prepare the data – Qualitative data can be collected in numerous ways, through observation, interview, focus group, questionnaire, case study. Irrespective of the collection methodology the researcher will generally transcribe the data into the form of text for
The research data for this work was collected through interview and questionnaire. The interviews were recorded and transcribed in their entirety to text. The questionnaire was an online data capture tool which allowed for the responses to be exported in text format for analysis.

2. **Define the Unit of Analysis** – Coding qualitative data usually involves the identification of themes, so the unit of analysis may be in the form of a word, phrase, sentence or paragraph, provided it is representative of a relevant theme as was the case in this work.

3. **Develop Categories and a Coding Scheme** – Pre-existing literature and theory can be a source for inductive category definition, while categories will arise deductively from the analysis of the text. Naming the categories or assigning codes supports systematic analysis. The themes identified during this work are outlined in Figure... <need to develop diagram of coding>

4. **Test Your Coding Scheme on a Sample of Text** – Before coding all data, a sample of text should be coded and reviewed for consistency.

5. **Code all the Text** – Once the coding scheme has been developed and tested, all data should be analysed and coded and any emerging themes incorporated into the coding scheme.

6. **Assess Your Coding Consistency** – This involves rechecking the consistency of the coding scheme after the data has been coded to ensure that ideas which developed during the coding phase were consistently applied to the entire data set. During this work the coding process was run over the entire data set three on three occasions.

7. **Draw Conclusions from the Coded Data** – After the data has been analysed and coded, the next stage is to draw meaning and inference from the analysis. Recurring themes and relationships should be identified and explored.

8. **Report Your Methods and Findings** – The findings of qualitative analysis should be both descriptive and interpretive. It is also important to report not only the findings, but also the decisions made in selecting the methodology of collection and analysis. The findings of this research are presented Chapter 4 and discussed in Chapter 5, while the methodology decisions are detailed in this chapter.

The steps outlined above are based on “Qualitative Analysis of Content” by Zhang and Wildemuth (2009, pp. 3-5).
**Research Limitations**

A number of limitations were present and acknowledged at the beginning of the research process, while others have become apparent as the research progressed as a result of acquiring a deeper understanding of the subject matter. The limitations which emerged during the research process have been used to inform recommendations for further research in the final chapter.

Given the time constraints in place, the number of interviews conducted was limited to 5. The response rate on the distributed questionnaire was not as high as had been hoped for. Both factors reduce the reliability of any generalisations made from the research. It should also be considered that the research may have been hampered by a potential reluctance among product owners or logistics service providers to discuss possible vulnerabilities in their supply chain processes. There may also be a reluctance to talk about organisational obstacles such as communication challenges which may be impacting operational processes or implementation of technological solutions.

**Researcher Bias**

It is important also to be cognisant of factors which may influence the researcher’s objectivity on the research topic. While experience in a particular field can be used as a justification for undertaking research in that area, so too can it influence interpretation of information or expected outcomes of analysis. This was noted by Bell and Thorpe (2013) is asserting that "a further problem arises when the management consultant or organization that has commissioned the study has a strongly favoured outcome which they hope will arise from it" (Bell and Thorpe, 2013). The researcher, while employed by a company which provides technology-based supply chain visibility services has made every effort not to steer or direct the interviewees in any particular direction with the line of questioning. The interviewees familiarity with the researchers employing organisation may have had an influence in the direction which participants took the conversation.
Data Analysis and Findings

Introduction

The purpose of this chapter is to present the results of the primary data collection. As outlined in the Research Methodology chapter, the primary data was qualitative in nature and collected using two methods – semi-structured interviews and an online questionnaire. The approach with the interviews was to present the interviewees with the same questions, in the same order, broadly in line with the research objectives. This approach was helpful in the data coding and analysis phase as the themes were covered in a similar order which aided grouping, analysis and comparison.

Interview Respondents

The approach to selecting interview candidates was to use the researchers’ professional network to identify at least 5 practitioners working at a supervisory or management level in some of the large global life science companies operating in Ireland. The targeted job titles tend to vary between companies, so titles including terminology such as; supply chain, logistics, export/ import, transport, operations, quality and security were selected. Eleven individuals fitting these criteria were identified and contacted by email. It was decided that I would use my professional email address to contact the potential candidates. It is acknowledged that this introduces a potential layer of bias, or influence on the collected data, however it was felt that emails coming from a student email address might be too quickly dismissed and which posed a risk given the narrow time horizon. The email contained an introduction outlining that I was a final year MBA student, that the research was part of the capstone project and a brief overview of the research followed by an invitation to participate in an interview. The responses received were mixed. No response was received from four candidates. Three candidates declined due to work commitments, or holiday conflicts. Four candidates replied in a positive manner and three of those eventually took part in an interview. As time constraints became more significant, it was decided to widen the parameters of the research to interviewees outside of Ireland and as a result, some further candidates were successfully identified.

The individuals who took part in interviews were all provided with the same Information Sheet and Consent Form (Appendix C) outlining the objectives of the research and providing assurances of anonymity:
Table 4. List of Interviewees

<table>
<thead>
<tr>
<th>ID</th>
<th>Functional Area</th>
<th>Industry</th>
<th>Location</th>
<th>Interview Date</th>
<th>Interview Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV1</td>
<td>Supply Chain Security</td>
<td>Biotechnology</td>
<td>Switzerland</td>
<td>22/06/2018</td>
<td>Telephone</td>
</tr>
<tr>
<td>IV2</td>
<td>Supply Chain Management</td>
<td>Pharmaceutical</td>
<td>Ireland</td>
<td>03/07/2018</td>
<td>Telephone</td>
</tr>
<tr>
<td>IV3</td>
<td>Logistics</td>
<td>Pharmaceutical</td>
<td>Ireland</td>
<td>03/07/2018</td>
<td>Telephone</td>
</tr>
<tr>
<td>IV4</td>
<td>Logistics</td>
<td>Pharmaceutical</td>
<td>Ireland</td>
<td>16/07/2018</td>
<td>Telephone</td>
</tr>
<tr>
<td>IV5</td>
<td>Logistics</td>
<td>Pharmaceutical</td>
<td>UK</td>
<td>20/07/2018</td>
<td>Telephone</td>
</tr>
</tbody>
</table>

**Interview Setting and Procedure**

Once the candidates had expressed a willingness to participate, they were asked to suggest some suitable times where they would be able to speak for approximately 45 minutes, preferably in a quiet and private environment. Having identified a suitable date and time, the interviewees were sent a follow up email approximately 48 hours in advance of the scheduled time, containing the Information Sheet and Consent Form (Appendix C) and the Interview Questions Form (Appendix D).

Each of the interviews was conducted over telephone. The interviewee was asked if they had read the provided forms, given a short brief and asked for permission for the conversation to be recorded. The interviews commenced once permission was given. Signed copies of the Information Sheet and Consent Form (Appendix C) were received and submitted to Dublin Business School.

The recorded interviews were transcribed by the researcher, within 24 hours of the interview taking place. It was felt that transcribing the data immediately after the interviews would benefit the analysis by maximising the researchers’ ability to recall and interpret sentiment expressed during the interview. The researcher chose to transcribe the recordings, rather than to use a third-party service. This was considered an appropriate approach due to the researcher learning style and to also to maximise the researchers’ exposure to the content.

**Structure of the Data Analysis Presentation**

The results of the data analysis are presented in the following order which mirrors the order in which the themes and data collection instruments developed during the research.
1. The research objectives and the priori themes which arose from the literature review and which informed the interview questions and are outlined.

2. The responses to the interview questions are presented with common themes outlined.

3. The responses to the questionnaire are presented.

**Research Objectives and Priori Themes**

A priori theme refers to a theme which the researcher has already considered in advance of the data collection process. Some priori themes are often present in the mind of the researcher in the form of research objectives and others usually emerge during the literature review process and will guide the data collection instrument design. The interview questions were written to explore the priori themes and research objectives and attempted to get the practitioners to speak openly and without prompting. The priori themes addressed by the interview questions were based in part on the experiences of the researcher as a practitioner and in part on the literature reviewed.

The interview questions were grouped under three broad headings shown below with the corresponding research objective:

**Supply Chain Visibility - Definition**

- Examine the perception of what the term *supply chain visibility* means to supply chain practitioners.

**Supply Chain Visibility Challenges**

- Identify the key supply chain visibility related challenges perceived by organisations.
  - Explore the possible barriers to achieving supply chain visibility.
  - Identify the supply chain visibility challenges with most financial impact.

**Supply Chain Visibility Technology**

- Explore the role technology plays in addressing supply chain challenges
  - Explore the potential role of IoT technology in addressing those challenges.
  - Identify potential applications for improving cold chain logistics using IoT.
Presentation of Interview Responses

The following section presents the themed questions asked and the significant or recurring topics which were received in response.

Supply Chain Visibility – Definition

The first question was aimed at probing the perceptions of supply chain practitioners on the meaning of the term supply chain visibility.

Please describe what the term ‘supply chain visibility’ means to you?

Several common themes were present in the answers, while some commonality in terminology was also present. Two respondents made very similar statements when summarising their thoughts on what supply chain visibility means:

“knowing where your product is coming from and going to at all times” (IV4)

“knowing where those components are at any given time” (IV5)

The complexity of global supply chains was highlighted by referring to the fact that there can be “multiple actors, multiple LSPs (logistics service providers), multiple carriers” involved. (IV1) Similarly, the multiplicity of stages in the supply chain was noted, “Whether it's being with the manufacturer, at a supplier, at a contract manufacturer, in transit, with a logistics service provider, on a container, in the sea, at an airport” (IV5). A concern was that despite having “good contractual agreements in place”, having comprehensive “end to end” visibility of the physical movement of goods is rare (IV1), while similar terminology was also used in expressing the desirability of “having an end-to-end view from order creation all the way through to the delivery to our customer” (IV3).

One respondent described two components of supply chain visibility – material flow and forecasting. Material flow being “visibility of critical or essential raw materials and finished goods, including safety stock at suppliers; right through to ... the last critical distribution of the product.” Forecasting being “the demands of our general markets, and ... the capacity constraints of suppliers” (IV2). Another also described two aspects of SCV, separating incoming “raw materials” and outgoing “finished goods” (IV4).
One respondent referred to quality both in relation to incoming raw materials and outgoing finished product, “knowing exactly where raw materials are coming from. And the other side of it is shipping our finished products out of our site and ensuring it makes it to our customers at the correct required temperature and that it arrives in an acceptable quality condition” (IV4).

Exception or event management was mentioned in the form of a desire for knowledge of the status of entities in the supply chain, and more specifically, actual status versus expected status - “what [product] in movement might be not moving as expected, might be disrupted, might be sent to the wrong place or stuck” (IV1). Visibility was also described as being an enabler for better decision making, “Having historical visibility data allows you then to optimize, so more data driven decisions” (IV1).

Supply Chain Visibility – Challenges

The next questions were aimed at exploring the challenges faced by current practitioners in the field around supply chain visibility.

Does your organization face any current challenges specifically around supply chain visibility?

Common themes addressed by respondents in response to these questions include; lack of standardization between IT systems, lack of integration between the data contained in the various systems, the fragmented nature of the industry and challenges around maintaining the integrity of cold chain logistics.

The multi-layered nature of the supply chain and in particular the transportation component is mentioned as a challenge due to the various visibility systems which may be in place at various transport companies. "Multiple layers of contracting and sub-contracting, within a supply chain and the multiplicity of systems ... how do you integrate that data?” (IV1). This is echoed by another respondent, “you need interfacing between systems ... our forwarder owns some of their own vehicles, so they have their own software but they’re also subcontracting to a number of other courier companies which again are all GPS tracked but are all run on different systems” (IV5).

While the technical aspect of data integration was mentioned, present also was the challenge of organisational willingness to share and integrate data. "Suppliers who might have their own software and their own IP ... aren’t going to be willing to share that ... to use on another company’s platform"
It requires the people that own the data - the transport company, the LSP, - to be willing to share that data and to push that data" (IV1).

The effect which mergers, acquisitions and divestment, both in the life science industry (IV2) and in the transportation industry (IV3), have on the ability to manage the supply chain was mentioned by two respondents as a challenge. A consequence of this, is that companies may be reluctant to invest in IT systems while they are involved in a potentially lengthy acquisitions or divestment process, and while uncertainty exist about what systems will be implemented going forward (IV2). The "distorting effect" caused by structuring and localisation of business for tax purposes was also cited as having an impact on supply chain activities (IV2). Restructuring in the freight forwarder industry was also mentioned as having a disruptive effect on supply chain operations and resulting in increased lead times particularly in relation to ocean freight (IV3).

The cost of implementing technology solutions to address supply chain visibility challenges was cited, "this visibility has a cost ... if you want CFOs and people who control budgets to buy into the underlying technology, there is a need to demonstrate that the cost of setting up end to end visibility is offset by the reduced risk of loss and damage" (IV1). "There is obviously the cost of the devices, there is the return logistics and the management of that, so cost is a thing" (IV5).

Concerns around data security were highlighted as a further barrier to the integration of supply chain data. One respondent stated that "you could eventually have a link to data that is highly confidential and private and so there is a concern over security" (IV2). This was echoed by another who said, referring to security and access control, "Previously our suppliers would be able to get in and look at our old systems, whereas they are prevented from doing that now" which, they added, has led to manual processes and workarounds being employed (IV3).

The sourcing of raw materials from emerging markets, such as China and India, was cited as challenging due to difficulty in ensuring that the product is coming from an exact location or specific manufacturing site which has been validated to comply with strict requirements (IV4). That sub-contracting within logistics and transport companies can lead to uncertainty about the precise routing or location of product was also mentioned, “freight forwarders may use a hub that we may not know about, that we haven’t qualified. So, we may not know exactly where our product is at all times” (IV4).

Are there specific challenges which have the most significant financial impact?
When asked specifically about challenges with a financial implication, common themes which surfaced were maintaining cold chain integrity (IV1, IV2, IV4, IV5) and the associated challenge of being able to action data quickly enough (IV2, IV5) and the cost of implementation of SCV solutions or hardware (IV1, IV5).

The importance of maintaining temperature of product throughout the supply chain featured extensively in the responses, “you’re handing your material over to a freight forwarder and they may not know the importance of maintaining the temperature control” (IV4). Another said, “I would need to be really comfortable before I would be happy sending millions of pounds worth of product in a container ensuring that it would always stay between 2 to 8, knowing that anything outside of that temperature would effectively mean a write off of that entire consignment” (IV5). In referring to the challenge of cold chain, the timeliness of the data was mentioned, “You may have a temperature logger on the product, but you may only get that data at the end of the journey” (IV4).

Temperature was also cited in relation to the cost of product loss, “Then there is a direct cost if that shipment is victim of disruption or theft, in both cases there could be spoiled goods, hence also tracking temperature” (IV1).

One respondent explained that routing decisions related to some shipments could be influenced by the perceived competence of some airports in term of cold chain logistics (IV2), while another made specific reference to risk of cold chain product sitting on a runway. Speed of reaction to available temperature data was mentioned by two respondents, “the challenge is if there’s a problem, hearing about it quickly enough so we can do something about it, and it doesn’t seem to matter how good the systems are, you do need a sort of a human oversight” (IV2). Referring to the similar issue of a temperature excursion taking place on a container in a terminal, another noted that even if communication paths were in place, “The chances are that it’s not going to be solved before a temperature excursion happens” (IV5). Another similar topic identified was shipping passive loads by air to other regions where time zones and working week variations such as in the UAE could create difficulty in contacting relevant parties in the event of customs delays or shipping exceptions (IV2).

The requirement to validate the equipment of third-parties was mentioned as a significant cost by one respondent, “We had to go about temperature mapping our freight forwarders trucks to ensure that they were able to meet our standards and maintain our temperature control and this was a very expensive project” (IV4).
One respondent interpreted the question as being the financial cost of not having supply chain visibility technology in place and mentioned the indirect cost of resources associated with having to actively chase the status of shipments when technology could provide that data automatically; “Having people to pick up the phone multiple times and say “where’s my shipment” is wasteful because you could have technology tell you” (IV1). They also mention the direct cost if a shipment is lost, stolen or spoiled, when technology could have been used to mitigate against that risk (IV1). Another respondent also referred to the cost of resources involved in managing multiple systems, “having different platforms and software to use and the resource of running that and actively tracking it can also be a bit of a challenge” and also referred to the cost of the visibility enabling hardware as a challenge (IV5).

One respondent referred to the challenge of reverse logistics when utilizing hardware to provide supply chain visibility, especially when dealing with third-parties, “Having reliability that we can always recover those devices can be a struggle” (IV5).

Another respondent referred to the cost of having containers sitting at a port as a result of restructuring in the freight industry, “you’re paying demurrage rates for your containers at port that don’t get on the vessel” (IV3).

**Supply Chain Visibility - Technology**

The final group of questions aims to probe what technologies are currently being employed and how developments in technology may be able to further address supply chain visibility challenges.

**Does your organization currently use any technology (software or hardware) in order to enhance supply chain visibility?**

The technology most often referenced in response to this question was Enterprise Resource Management software. Also featuring strongly in the responses was hardware to provide data about product temperature and location.

The three respondents who spoke about ERP systems all use the same brand of system and a variety of modules were mentioned in relation to that particular system.

“We implemented [the ERP] on an enterprise wide system ... that includes warehouse management, order management and finance modules” (IV2).
“We use [the ERP] in this regard. We have a manufacturing version of it and we have a commercial version ... We are working on a VMI (Vendor Managed Inventory) module, that is integrated with [the ERP] ... [the ERP] system, that generates the purchase orders, is all done by MRP (Material Replenishment/Requirements Planning)” (IV3).

“In terms of supply chain visibility of where our raw materials come from we use [the ERP]. Our vendors would be approved on [the ERP] so we ensure that our raw materials are coming from those approved vendors” (IV4).

Two respondents spoke about using GPS tracking systems to track products for the purposes of enhanced security. “We are using GPS trackers on road transportation with geofencing ... for security reasons ... When we are shipping controlled drugs by sea, we are using other devices as well which is tracking location and also giving enhanced security on to the container itself in terms of - has it been opened?” (IV5). “Our shipments are using a device which gives geolocation of a given shipment” (IV1).

Two respondents referred to the use of data loggers for tracking the temperature of shipments in transit. “that one is really critical for our products because we are actually releasing product based on data that comes from the [temperature data loggers]” (IV5). “[Temperature data loggers] track our temperature outbound” (IV4).

Electronic Data Interchange (EDI) was mentioned by two respondents. “In terms of looking after the material downstream the basic approach has been just to use EDI and rely on the warehouse management systems by the 3rd party logistics providers” (IV2). “One thing that we really starting to look at now is how we interface with our logistics service providers. Can we automate bookings through EDI, so giving our forwarder visibility of what’s coming up and when shipments are going?” (IV5). One respondent spoke about their organisation having a road map to a supply chain visibility platform which would integrate data from multiple data sources.

**Do your logistics service providers give you tools that enhance supply chain visibility?**

Many of the respondents indicated that several of their transportation companies provide online portals which provide them with access to information about the status of their material flows. In relation to being able to access information about products, orders or shipments while they were in transit, some interviewees explained that using multiple transport companies presented a challenge from the point of view of having to access multiple different portals. One commented that “there are as many platforms as there are partners” (IV1). Another interviewee mentioned four
different transport providers and described four different processes for accessing information about shipments in-progress (IV2).

Others described how requests for information about moving product were generally done manually, either by telephone or by email. One respondent described how they addressed the challenge of trying to access data from multiple providers and systems by implementing an “end-to-end” partnership with a single transportation and logistics provider who gives them real-time visibility of shipments through an online portal as well as reports on volumes and metrics such as on-time delivery; “We can go into their portal and find out where our containers are at any given time” (IV3).

The fact that shipment progress is often based on reaching static waypoints was alluded to by one respondent, “a lot of these platforms only give you static feedback, as in pallet has reached a waypoint and then you don’t hear anything until it has reached the airport” (IV1), while two others when probed on the question of in-transit notifications explained that transport companies provide them with information in the event of an exception. One explained, “we would expect them to tell us if something hasn’t met a milestone which we expected it to” (IV5), while the other described how the transport company could provide a history of receipt notifications for a shipment journey but that it would only be in a case when product damage was discovered, “if our product arrived at our customers site and we got a notification to say that there was damage to the product” (IV4).

One respondent described how they have access to GPS tracking data from systems installed in the vehicles of some of their transport companies (IV5), while another described how they use portable GPS devices supplied by a third-party provider to track product on specific high-value product movements for the purposes of visibility and security (IV1).

One of the respondents interpreted the question in that, by operationally supporting requests for the use of temperature data loggers or other third-party devices such as security devices, logistics service providers were indirectly providing tools which enhance supply chain visibility. They noted that, “at the moment in terms of visibility they’re not particularly offering us much more than that” (IV4).

Periodic reporting of inventory from third-party warehouses was referred to by one of the respondents (IV1).
**Internet of Things**

Internet of Things is a term used broadly to describe the wide range of interconnected devices which autonomously collect and exchange data without the requirement for human intervention. There are numerous applications for the technologies and the research aimed to explore potential use cases in the field of supply chain visibility.

*What is your understanding of the term Internet of Things?*

Most respondents had some degree of familiarity of the term Internet of Things and referred to equipment, objects or devices being connected and capable of sending, receiving or exchanging data with each other or with other systems.

Each interviewee was then given approximately the same explanation of Internet of Things, “interconnected electronic devices which collect data and exchange information with other systems without the requirement for human interaction” and then asked if they were aware of this type of technology being used within their organisations.

*Is your organization currently using any Internet of Things technology to address supply chain visibility challenges?*

Many of the responses to this question were a reiteration of topics which had been answered in response to previous questions, most notably, the use of temperature data loggers and GPS tracking on product in-transit for quality and security purposes.

One described how they have real-time inventory quantity and location data accessible on mobile devices, “from our third-party warehouse you can see from an app that they provide us, you can see where a pallet is located. I can type in the material number is it will tell me how many there are” (IV3).

When speaking about the use of IoT devices for real-time location of product in transit, one respondent pointed out that the devices and the data from the devices are simply an enabler for delivery of service and commented on the perceived need for an ability to pull data from multiple data sources and device, irrespective of the manufacturer.

A respondent referenced environmental control and monitoring systems when probed, “in the warehouse we would have temperature and humidity systems which are all online and monitored” (IV4).
Real-time information about volumes at a port viewable on mobile devices was referenced by one of the interviewees (IV3).

**Additional Questions which Emerged**

The above questions were the prescribed questions which were asked to each interviewee. Some additional questions emerged during the interviews which were asked to only a sub-set of the respondents.

*Are you aware of any initiatives underway or upcoming in your organization which may use IoT technologies for enhanced supply chain visibility?*

One respondent articulated the desire to use interconnection of systems to automate or assist with the automation of downstream activities such as booking transports with their logistics service providers by providing forecast data of upcoming shipments, so “*they can start building up shipments based on the information signals from our system*” (IV5). This response may have been more associated with EDI rather than Internet of Things.

*What are the potential additional benefits of the data collected by these types of SCV systems (GPS tracking of product in transit)?*

The topic of using devices which capture both temperature and location data was discussed by two interviewees. One spoke about the challenge of measuring and mapping Time out of Refrigeration (sometimes known as TOR, Time out of Storage (TOS) or Time at Room Temperature (TRT)) for temperature sensitive shipments, “*shipping with a device that gives you location and temperature, so that we can determine how much time typically and in what location typically does that package, parcel, pallet sit outside of refrigeration*” (IV1). Similarly, another respondent mentioned in answer to an earlier question that they are beginning to utilize devices capable of collecting temperature and location data to better understand the characteristics of their product in transit (IV5).

**Questionnaire Respondents**

The survey respondents were identified in a similar method to the interview respondents through judgement sampling. Contacts were selected using the following criteria; they should be employed by a life sciences organisation or by an organisation providing logistics or transport services to life science organisations and should be working in a supply chain, information technology, or project
management related role. Categorisation questions were included at the beginning of the questionnaire which allowed for the categorisation or filtering of responses.

Approximately 50 candidates were identified and contacted using my professional email address. The email contained an introduction outlining that I was a final year MBA student, that the research was part of the capstone project and a brief overview of the research followed by an invitation to participate in a short survey and a link to the online questionnaire. In an effort to “snowball” the sample, each invitation also asked that the respondent share the survey link with any of their relevant colleagues. The questionnaire was distributed in online format which included on the front page a brief overview of the research and an assurance of the confidentiality of the collected data along with the option to opt out at any time. The survey participant was given the option to continue the questionnaire by accepting that they had read and understood the overview and that they were taking part voluntarily.

**Presentation of Questionnaire Responses**

The following section presents the questions asked and the answers which were given in response. Survey responses were received from 25 respondents. The questionnaire had two initial categorisation questions:

*Which of the following best describes the area in which your organization operates?*

![Operational Area of Organisation](image)

*Figure 10. Operational Area of Respondent Organisation*
Which of the following best describes the functional area in which you operate?

The majority of respondents were in logistics, distribution or supply chain.

![Functional Area of Respondent](image)

Figure 11. Functional Area of Respondent

Please evaluate the following statement. Supply chain visibility in the life sciences industry is:

This was a general sentiment question which attempted to gauge the level of importance the respondents attach to supply chain visibility for life science companies. The respondents were given a five-point scale. 54.2% responded 'Extremely Important' while 45.8% responded 'Very Important'.

![Importance of Supply Chain Visibility](image)

Figure 12. Importance of Supply Chain Visibility in Life Sciences
The following two questions attempted to probe the perceptions of supply chain visibility definition and type.

**Please select which of the following definitions you think best describes supply chain visibility:**

This question presented four definitions of supply chain visibility which had been proposed by prominent authors discovered during the literature review. The questionnaire software was configured to present the definitions in a random order to reduce the risk of position bias influencing the selection.

*The awareness of, and control over, specific information related to product orders and physical shipments, including transport and logistics activities, and statuses of events and milestones that occur prior to and in-transit.* (44%)

*A process of collecting supply chain data, integrating it, extracting intelligence from it and using that intelligence to interrupt decisions in a cross-organizational supply chain oriented context.* (32%)

*The extent to which actors within a supply chain have access to or share information which they consider as key or useful to their operations and which they consider will be of mutual benefit.* (12%)

*The identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events.* (12%)

**Figure 13. Supply Chain Visibility Definitions**
Please evaluate the importance of the following types of supply chain visibility:

This question presented seven types of supply chain visibility which had been proposed by McIntire (2014) and discussed during the literature review. The respondents were given the same five-point scale as previously.

![Importance of Supply Chain Visibility Types](image)

Figure 14. Importance of Supply Chain Visibility Types

The following four questions attempted to probe the perceptions of supply chain visibility solution implementation with reference to evaluation criteria proposed by McIntire (2014).
**Has your organisation implemented a supply chain visibility solution in the past 12 months?**

64% of respondents said that their organisations had implemented a supply chain visibility solution, while the remaining 36% said that they either hadn’t or weren’t sure. It is important to note that some of the respondents are likely to work for the same organisations.

![SCV Solution Implemented](image)

*Figure 15. Supply Chain Visibility Solution Implemented in Past 12 months*

Please select the most appropriate statement in relation to the data collected by the recently implemented supply chain visibility solution:

![SCV Solution - Data Capture](image)

*Figure 16. Supply Chain Visibility Solution Data Capture*
Please select most appropriate statement in relation to the data integration of the recently implemented supply chain visibility solution:

![SCV Solution - Data Integration](image)

Figure 17. Supply Chain Visibility Solution Data Integration

Please evaluate the following statement in relation to the recently implemented supply chain visibility solution:

![SCV Solution - Supports Decision Making](image)

Figure 18. Supply Chain Visibility Solution Decision Making
Please evaluate the following potential barriers to supply chain visibility:

This question attempted to probe the perceptions of the respondents to potential barriers which may exist that prevent organisations from achieving supply chain visibility. This question was informed by themes which emerged during the preliminary analysis of the interview data.

![Figure 19. Significance of Potential Barriers to Supply Chain Visibility](image)
'Internet of Things' refers to the interconnection of electronic devices allowing them to send and receive data. Does your organisation use this type of technology to capture data about the identity, location, or status of product or orders in your supply chain?

36% of respondents said that their organisations utilised Internet of Things technologies to capture supply chain data, while the remaining 64% said that they either didn’t or weren’t sure. It is important to note that some of the respondents are likely to work for the same organisations.

![Figure 20. Use of Internet of Things for Supply Chain Data Capture](image)
Does your organisation use technology to give you real-time information about any of the following? Please select all that apply.

This question attempted to probe the availability of real-time information about supply chain entities. The respondents who selected other had a free text option to provide a description, however none did.

![Available Real-Time Data](image1.png)

**Figure 21. Availability of Real-Time Data**

**Please evaluate the importance of the following:**

This question attempted to probe the sentiment towards having knowledge of location and temperature of product while in-transit using the same five point scale as before.

![Real-Time Data - Product in Transit](image2.png)

**Figure 22. Importance of Real-Time Data for Product in Transit**
The final three questions were open ended and attempted to further probe the respondents about their experiences around supply chain visibility challenges or solutions. The responses tended to be written in shorthand, so it was not always possible to infer the complete meaning or sentiment but where possible they have been interpreted and grouped together.

*Please briefly outline a current supply chain visibility challenge faced by you or your organisation.*

This question was designed to gain further insights into the concerns and challenges faced by supply chain practitioners. A number of topics were mentioned by the respondents which were categorised into five groups and are outlined below.

![SCV Challenges](image)

*Figure 23. Types of Supply Chain Visibility Challenges*
Imagine you have been given budget to implement a system to address a supply chain visibility challenge tomorrow. Please briefly describe the functionality of the system you would choose to implement.

This question was designed to gain insight into the types of systems the respondents would choose to implement if they had the resources to do so. The responses to this question were also very closely aligned with the interview discussions. Two main aspirations clearly emerged – a desire for real-time tracking of the location and environmental condition (temperature, humidity) of product transiting the supply chain; and integrated inventory management systems which provide full visibility of all product and material irrespective of geographical location. Automation of vendor approval or qualification was also referred to.

![Desired SCV Systems](image)

**Figure 24. Desired Types of Supply Chain Visibility Systems**

Please add any additional comments you may have about supply chain visibility, supply chain visibility challenges or supply chain visibility technology.

The final question provided the respondents an opportunity to outline any additional comments or thoughts which they felt were relevant and not already covered. The response rate to this was low and the topics were varied, including the challenge of the reverse logistics of tracking and temperature devices, the collaborative nature of the supply chain, integrating into the telematics systems of supply chain partners and the desire for availability of automated real-time or near real-time updates about supply chain events regardless of office hours.
Discussion of Findings

Introduction

There was significant overlap evident in the topics which emerged from the data collected during the research. In this chapter, the interview data and questionnaire responses will be aggregated and the themes which emerged from the analysis of the collected data will be outlined. The themes will be discussed and put into context against the relevant research objectives and literature.

Research Objective 1 – Supply Chain Visibility Definitions & Perceptions

- **Examine the perception of what the term supply chain visibility means to supply chain practitioners.**

The literature points to a dichotomy in the field of supply chain where despite supply chain visibility featuring highly as a priority of supply chain practitioners, there exists a lack of clarity or consensus on what exactly is meant or understood by the term supply chain visibility (Bradley, 2002; McCrea, 2005; Francis, 2008; McIntire, 2014). The research attempted to probe this among practitioners in the life sciences and to identify commonalities which may exist.

Supply Chain Visibility - Definition

The research indicates that supply chain practitioners in the life science industry basically view supply chain visibility as having knowledge about material or about demand for that material. There is a prevailing sentiment that in an industry where the supply chain can have a large number of actors and entities, information about material or demand can be difficult to access or predict. The research suggests that there is an acceptance that the information already exists, or that the data from which the information could be built already exists. However there appear to be challenges in accessing the information in a way that is coherent and useful. It could be said therefore that the desire for supply chain visibility is to have the requisite information in easily accessible in a useable format. This is strongly in alignment with the **accessibility** dimension the four dimensions model proposed by Papert et al (2016).

All questionnaire respondents evaluated that supply chain visibility for the life science industry was either “very important” or “extremely important”. This supports the findings of Francis (2008) who found that supply chain visibility features strongly as a priority for practitioners.
The questionnaire presented four definitions of supply chain visibility from the literature and asked the respondents to identify which one they thought best described the term. 42% and 33% of respondents chose the following definitions respectively:

“The awareness of, and control over, specific information related to product orders and physical shipments, including transport and logistics activities, and statuses of events and milestones that occur prior to and in-transit” (Heaney, 2013).

“Supply chain visibility is a process of collecting supply chain data, integrating it, extracting intelligence from it and using that intelligence to interrupt decisions in a cross-organizational supply chain oriented context” (McIntire, 2014).

It is noticeable that the two definitions which were selected most frequently as the most appropriate, were the two most recent definitions presented. Perhaps this is an indication that as the paradigm of supply chain visibility evolves, the definitions presented to describe it are evolving to become more accurate.

**Supply Chain Visibility - Types**

McIntire (2013) describes eight types of supply chain visibility and specifically relates three of them to the pharmaceutical industry. The research attempted to gain an insight into how these various types of visibility were considered by practitioners. It should be understood, that the respondents may not have been familiar with the terminology used by McIntire (2013) to name the visibility types. They were given the visibility type name and a brief one sentence description. Interestingly, the three types of visibility which scored highest among the questionnaire respondents were the three which McIntire specifically linked to pharmaceutical in his book.

1. A given product’s life-cycle events. (Lot and Serial Number Tracking)
2. The total view of all inventory regardless of location. (World as a Warehouse)
3. The capability to infer the correct action from a pattern of important facts. (Event Management)

Also interesting was the fact that the visibility type which scored highest among the questionnaire respondents, Lot and Serial Number Tracking, did not feature as a significant theme in the analysis of the interview data as it was mentioned by only one of the interview respondents. This was surprising as serialization and traceability is highly regulated within manufacturing of
pharmaceutical and medical device products. The themes associated with World as a Warehouse and Event Management did feature extensively in both the interview data and the data collected from the questionnaires.

4. *The status of a given object in the supply chain versus its expected status.* (Status Visibility)
5. *Whether or not inbound product will arrive on time.* (Inbound Track and Trace)

The topics of Status Visibility and Inbound Track and Trace were mentioned frequently in both the interview and survey data, so it was not surprising that both ranked highly in the survey.

6. *The correct physical location of a supply chain entity?* (GPS Tracking)
7. *A view of competitor’s supply chain(s).* (Competitive Market)

The two visibility types which attained the lowest scores on the questionnaire were GPS Tracking and Competitive Market. It is important to note that both did feature as important overall, so the low score was based on a comparison with the other visibility types. The overall data analysis suggests that physical location of material was of very high importance to almost all respondents, so the relatively low score in this section of the survey seems at odds with the overall findings. It should be noted that the relatively low number of completed questionnaires reduces the generalizability of findings (Check & Schutt, 2011, p. 161).

**View of Material Flows**

The respondents all referred in some manner to supply chain visibility being connected with having knowledge about the movement of goods in their supply chains; incoming raw material (upstream) and outgoing finished product (downstream). The term “end to end” was used frequently both in interview responses and in the questionnaire comments. The desire to have knowledge of the location of material across the supply chain was evident. Many participants expressed the desire to know the location of raw material or finished product. The definition of location could be interpreted as being either the geographical location or in some cases the ownership or custodian. Evident from the data is that the flow of material can involve numerous supply chain actors; raw material suppliers, external warehouses, external logistics or transport providers. The ability to have a comprehensive view of material despite this multiplicity was frequently referenced. Additionally, visibility encompasses not only location and ownership, but also quantity and status or condition. These attributes are consistent with those of Papert et al (2016) and Francis (2008). Relating to status, environmental state such as temperature or humidity featured prominently as a
The topic of environmental condition of material is further explored when the emergent themes around supply chain visibility challenges are discussed.

**Decision Support**
Also evident from the data collected on defining supply chain visibility, was the requirement for visibility to act as an enabler for improved decision making. This supports much of the literature including that of Barratt and Oke (2007) and (Goh et al, 2009), which posits that an important aspect of visibility is the ability to improve decision making. This manifested in two primary ways in the research.

**Forecasting**
The concept of visibility extended beyond knowledge about the status or location of physical product to knowledge of external forces. The potential to harness knowledge of supplier constraints or market demands to maintain the integrity of the supply chain emerged as a definition for or outcome of supply chain visibility. Having visibility of such influencing factors allows for decisions to be taken which may minimise supply chain disruption due to unforeseen increased demand or supplier shortages.

**Exception / Event Management**
Participants identified that having supply chain visibility offers the opportunity to identify events or exceptions, allowing for corrective action to be taken which may also minimise the risk of disruption. Disruption can occur for various reasons. Transportation delays can impact the supply chain either directly or indirectly, by impacting the stability of temperature sensitive material. Conversely, temperature excursions can cause delays by requiring additional auditing or processing. Additionally, material transported within life science supply chains can be of high value and as a result can be the target of criminal activity.

Having measures in place to mitigate against these types of disruptions or to implement damage limitation measures in response to events emerged as a significant driver for increased supply chain visibility.
Research Objective 2 – Supply Chain Visibility Challenges

- Identify the key supply chain visibility related challenges perceived by organisations.
  - Explore the possible barriers to achieving supply chain visibility.
  - Identify the supply chain visibility challenges with most financial impact.

The literature highlights the difficulties associated with achieving integration of data about supply chain entities between supply chain actors (Francis, 2008; Romano, 2003; Holcomb et al., 2011; Jeyaraj and Sethi, 2012). The research in relation to challenges around supply chain visibility strongly supports this.

Barriers to Achieving Supply Chain Visibility

Several topics emerged from the data collected in relation to supply chain visibility challenges and the barriers to achieving visibility.

Industry Complexity

The subject of organisational and inter-organisational complexity and its impact on the supply chain and supply chain visibility arose in a number of forms. Organisations within the life science industry are currently subject to frequent structural changes in the forms of acquisitions, mergers and divestments. As an industry in the mature phase of its life-cycle, many organisations are achieving growth or expanding their product portfolios through acquisition or merger. Structural configurations also exist within the life sciences industry which are designed to maximise financial benefit from favourable tax policies and which can result in additional complexities.

Challenges around supply chain visibility which stem from this fragmented industry landscape arise in a number of forms. One of the most referred to consequences is the effect on technology implementation, and data integration which will be discussed in later sections. Complexity is not confined to life science producers themselves but also extends to the wider supply chain, with logistics service providers also subject to reorganisation and hierarchical configurations. Prevailing structures within the transport industry have a strong influence on the availability of data to product owners.

Difficulty in Achieving Data Integration

The fragmented industry landscape outlined above directly impacts supply chain visibility. For example, there is a myriad of online portals available to view status information about product in
As alluded to previously, it is not a lack of available data which is the challenge, it is that the data exists in separate systems which causes difficulty. A repeated sentiment from practitioners was that even though portals were available from suppliers, the resources were not present within the organisation to adequately make use of them due to the requirement to access multiple systems.

The topics which emerged relating to challenges were similar across interview and questionnaire responses. As mentioned above a frequently occurring topic is that of the challenges around integrating data from the various systems owned by various supply chain parties. Accessing data from third-party systems, integrating it with data from other systems, automation of data integration tasks, and the challenge of system multiplicity due to industry mergers and acquisitions all featured in the responses. The challenge of acquiring “End to End” visibility including that of product in transit and having to rely on updates from supply chain partners was referred to by multiple respondents as a concern.

Aside from the technological difficulties in integrating data, another topic which emerged is the challenge of organisational willingness to share data with other members of the supply chain. Concerns over security and intellectual property featured as barriers to data sharing which in turn serve as obstacles to achieving supply chain visibility. Service providers simply may not wish to give other organisations access to their data, particularly if the data is linked to the service providers unique selling point.

**Technology Implementation**

In addition to the difficulty in integrating data from various systems, a challenge cited was reluctance or inability to implement suitable systems. Two contributory factors emerged. With an industry subject to frequent mergers and acquisitions, some companies or divisions of companies find themselves with data about inventory or orders residing on multiple ERP systems. Reconciling this data into a single unified view emerged as a challenge and an aspiration. This is closely aligned to the World as a Warehouse visibility type described by McIntire (2014). Additionally, some practitioners found that their organisations were unable to implement technology solutions due to uncertainty about whether existing systems would be maintained or would be replaced by the systems used by the organisations which they had been merged with or acquired by. In some cases, technology rollouts were taking prolonged periods of time resulting in divisions of the same
organisation operating different systems or different versions of the same system necessitating workarounds and creating data access issues.

**Emerging Markets**

Challenges associated with the sourcing of materials from emerging markets featured in the data. Regulatory differences between regions may require organisations to perform auditing activities on the manufacturing sites from where product is sourced. Being sure that material is originating from the specific validated site is not always possible. Challenges around ensuring the integrity of cold chain logistics in these markets was cited by some respondents as a concern. Potential for Internet of Things technologies to address cold-chain and chain of custody challenges will be discussed in a later section.

**Financial Impact of Visibility Challenges**

When exploring the subject of supply chain visibility challenges with the most significant financial implications, the most prominent findings were in relation to cold chain logistics and cost of implementing visibility measures.

**Cold Chain Logistics**

It is not surprising that the potential financial impact of a temperature excursion featured extensively as a concern for supply chain practitioners. A temperature excursion occurs when temperature sensitive product or material is exposed to a temperature outside of its required temperature range. Loss of revenue can occur due to a shipment being quarantined while an investigation takes places due to the resultant delays and additional cost of resources to carry out the investigation. Further losses would be incurred if that product is ultimately deemed to be unusable. Temperature excursions can happen at various points during the supply chain. As discussed previously, the layers of sub-contracting present in the transportation industry poses a significant obstacle to maintaining visibility of the cold chain. A number of respondents spoke about the risk to product while in transit as significant. Organisations involved in cold chain logistics have a number of mitigation measures available to reduce the risk posed by temperature excursions. Depending on the requirements and stability of the product it can be shipped using active or passive measures. Broadly speaking active shipments involve the use of powered refrigerated transportation assets, such as refrigerated vans, trailers, containers or other specialist powered units. Passive shipping involves the use of non-powered insulating or cooling packaging such as polyurethane or gel packs. Temperature loggers which travel with sensitive product and produce a
temperature history of the shipment are used to ensure that the material can be accepted at the receiving end.

The research found that there is a strong desire among practitioners to avail of technology developments to provide real-time data about the temperature and location of product in transit. The application of this type of technology will be discussed further in relation to the findings of the next research objective.

**Cost of Visibility Implementation**

Some participants cited the costs associated with implementing supply chain visibility solutions as a visibility challenge with a financial impact. Although this was not how the question was intended is highlights a valid concern. It was not only the cost of the technology solutions which were referenced but also the cost of having resources available to manage that solution. An opposing viewpoint taken by one of the respondents was that there is a cost associated with not implementing visibility solutions. Technology can be used to enhance decision making in order to mitigate against direct costs incurred due to the types of disruption outlined previously. Additionally, technology can be used to reduce indirect costs. An example given outlined the cost of having somebody reaching out to a supplier for updates on the status of a shipment, when having a technology solution in place could allow for that information to be provided automatically. Cost benefit analysis should be used provide data to support or oppose visibility implementations.

**Research Objective 3 - Supply Chain Visibility Technology**

- **Explore the role technology plays in addressing supply chain challenges**
  - Explore the potential role of IoT technology in addressing those challenges.
  - Identify potential applications for improving cold chain logistics using IoT.

The literature demonstrates the importance of information exchange and the inextricability of supply chains, their associated information flows and the supporting technologies (Radstaak and Ketelaar, 1998; McIntire, 2014; Hill and Scudder, 2001; Cooper, 2006; Qui et al., 2015). One of the most striking findings of the research was that the many of the challenges perceived by the participants were directly associated with technology.
Technologies Used to Address Visibility Challenges

The most frequently referenced supply chain visibility technologies were ERP systems, temperature data collection instruments and GPS tracking systems. ERP systems were generally discussed in relation to warehouse management and inventory control. The use of temperature data loggers is prevalent among those who are shipping temperature sensitive material or product. GPS tracking technology is being used by some organisations who are involved in shipping high value material or product. The concept of fragmentation and the challenges it presents as discussed in the previous section, extend beyond the organisational and into the technological. The three technologies discussed – ERP, GPS and temperature measurement tend to exist as separate systems. There was some consensus among the discussions with interviewees that integration of these types of systems is desirable.

The availability of third party tools aimed at enhancing supply chain visibility for supply chain partners was evident. The most frequently encountered types of systems in the research were portals offered by logistics service providers where shippers can access information about the status or location of product in transit. The views on the success or usefulness of these systems was varied. In some cases, the product owners expressed satisfaction with the systems, however in many cases the practitioners admitted the systems though available were not used.

Application of Internet of Things

Internet of Things refers to the connectivity of devices and object allowing them to exchange data. The addition of internet connectivity to supply chain hardware has brought the Internet of Things into the supply chain visibility paradigm. Examples include vehicle tracking systems, connected containers and environmental monitoring systems (Bauer et al, 2014). Smaller devices are also becoming more widely available. Devices which can measure temperature and or other environmental conditions as well as location and transmit that data via the mobile phone network to a centralised system offer real-time or near real-time access to data which is potentially important to supply chain practitioners. Among the applications being used by respondents were monitoring of shipment location, motion status and container door seal status for security purposes.

There is potential for IoT technologies to address some visibility challenges described in the research. Certainly, access to timely information about the status of an order or a material flow is made possible by IoT technology. Practitioners repeatedly expressed the desire to have knowledge
of the location of material in transit. Low-cost devices of similar size to a smart phone, with sufficient autonomy to last several weeks or months, and capable of transmitting location, and other environmental information several times per hour, are readily available. Access to real-time location data can be used to infer a number of potentially useful things. Current location or GPS coordinates can potentially infer the custodian of a product or order or indicate whether a shipment will arrive on time. It can also confirm if the product has originated from the correct manufacturing site or was staged at a validated storage facility. Notification of these types of events can be automated with the addition of geofencing and time-stamping. It was evident from the research that this type of visibility was desirable, 62.5% of the questionnaire respondents who described a visibility system they would implement if given the resources, proposed either real-time location, real-time temperature or both.

The availability of the technology and data however does not sidestep the difficulties associated with data integration and availability. Many of the providers of such technology may themselves further complicate the landscape by introducing additional systems to the already crowded arena.

**Applications of IoT for Cold Chain Logistics**

Real-time access to temperature data of product in transit is also made possible by IoT. Some devices capable of providing this information are also capable of combining the temperature information with geo-location data. This further expands the capabilities outlined above for identifying exceptions or events. It also provides the opportunity to identify not only, if temperature excursions are taking place but also where they are taking place. Considered analysis of this type of data could prove useful in mapping supply chains, identifying risk areas and identifying potential quality assurance issues of supply chain partners. Geotagged temperature data can provide product owners with information that could be used to map Time out of Refrigeration and where that ToR occurs. Decisions about product routing, transportation mode or optimisation of packaging could be taken based on this type of information.

The discussions around technology uncovered many challenges, much of the discussion related to difficulties in integration of data from multiple systems or sources. An additional topic which arose was the challenge of how to action data in an effective manner. This specific topic was discussed by three interviewees independently. In each case the interviewee broadly described the following scenario. A temperature sensitive shipment is sitting in a shipping container at a port, or in a unit load device (ULD) at an airport. Real-time temperature data is communicated by an IoT device
inside the container to a supply chain visibility system at the manufacturer facility. A notification alarm is received by supply chain or quality control indicating that the temperature inside the container is beginning to rise towards the limit of its acceptable range. The challenge illustrated was the difficulty in being able to action this information quickly enough to prevent a temperature excursion from taking place. It would require a significant communication and coordination effort to result in having somebody physically interact with the shipment in time to make corrective action. This was not a technology limitation, but a restriction caused by having to rely on human intervention in a situation where communication channels would be complex. Of course, it should be mentioned that this is a particularly extreme example, but one which requires consideration.
Conclusions and Recommendations

Conclusions

The findings of the research lend support to much of the existing literature. Supply chain visibility is a topic that, while appearing to contain slightly different nuances for different practitioners, has an overall thrust that is universal. Supply chain practitioners fundamentally view supply chain visibility as having knowledge and consider that knowledge to be an enabler for decision making.

The Data Information Knowledge Wisdom (DIKW) hierarchy provides an appropriate framework against which the various states of supply chain visibility data can be aligned. While Ackoff (1989) is credited with the first academic articulation of the hierarchy, earlier artistic works by Eliot (1934) and Zappa (1979) also featured connections of the terminology (Ackoff, 1989; Rowley, 2006; Sharma, 2008).

![Figure 25. Data, information and knowledge, (Chaffey and Wood, 2005)](image)

The research suggests that there is an abundant availability of data. If the data is processed appropriately, information and knowledge should follow. A theme which frequently arose in the research was the fragmented nature of systems. If the obstacles preventing integration of those systems and the data residing within them can be overcome, then it should be the case that the extraction of intelligence from the data should become a simpler task. The research indicates a strong consensus between practitioners that a significant barrier to supply chain visibility is one of
data integration. It suggests that despite the availability of the technologies and requisite data to overcome supply chain visibility challenges, there exists a difficulty in integrating and accessing that data in a manner which is coherent, supports decision making and adds value by driving operational efficiency. Perhaps it could be said that the major challenge now faced, is the matter of data presentation.

The discovery of the degree to which technology itself presents a challenge to supply chain visibility was somewhat unexpected. It became evident early on that one of the major recurrent themes was that the technology itself presented a significant challenge. There is a prevailing sentiment which points to a frustration at the lack of interoperability between supply chain related systems. The researcher proposes that information technology is no longer separate from the processes it has developed in support of. At the commencement of the research project the researcher had conceptualised supply chains as entities which faced challenges that needed to be addressed. Concurrently, information technology was considered as a tool which could be applied to supply chains in order to overcome those challenges. While this may be true to a certain extent, it is now apparent that the reality is closer to one in which supply chains are as much constructed from the data which they generate as they are from the materials they convey and the organisations they connect.

Two main aspirations emerged from the research – a desire for real-time tracking of the location and environmental condition of product transiting the supply chain; and integrated inventory systems which provide full visibility of all product and material irrespective of geographical location. Perhaps with a coherent method of presentation of this data, the two desired outcomes can be combined into one system.

**Answering the Research Question**

The research project attempted to answer the following question:

**What are the visibility challenges faced by supply chain practitioners for life science companies and can they be addressed using Internet of Things technologies?**

While the research demonstrates that several distinct visibility challenges are faced by life science practitioners, the researcher proposes that the overall challenges can be summarized as follows. Complexity within the industry introduces complexity into the supply chain. This complexity is present in the form of multiple actors, multiple systems, multiple sources of data and multiple
constraints. Additionally, there is no one single type of supply chain practitioner, so it is difficult to find single solutions which satisfy the requirements of the various interested parties. At a high level, perhaps the key to supply chain visibility is being able to identify the relevant information, make it available to the appropriate parties, presented in a suitable format to support decision making. The research has identified that real-time location and environmental sensing data feature prominently in the requirements of practitioners. This clearly indicates that Internet of Things technologies have a role to play in collecting data which is relevant to supply chain decision making. What is evident also, is that IoT alone cannot address supply chain visibility challenges. IoT can act as an enabler to collect and provide data but that data must be processed by appropriate systems and turned into information which can be used to generate knowledge that enhances decision making capabilities.

The below conceptual framework seeks to represent flow of supply chain data by demonstrating how the DIKW model of Ackoff (1989) on the right, aligns with the meta-steps of supply chain visibility model proposed by McIntire (2014) on the left.

**Figure 26. Conceptual Model of Supply Chain Visibility Data**

**Recommendations**

**Recommendations for Further Research**

It is evident that the subject of supply chain visibility has many aspects which merit further exploration. An initial recommendation would be for a more extensive research undertaking which could access data from more respondents.
An investigation into the availability of online tools and the use of such would be valuable. Perhaps with a particular focus on usability or user interface to attempt to identify why some systems which were available but not used.

The need for a more open platform or standardized approach to collecting of data, not only from IoT devices but also from unconnected IT systems, is evident. This goes back to the subject of data presentation. A valuable insight would be to explore among practitioners, how best to visualise data relating to the supply chain.

Further research into the experiences of organisations and practitioners who have implemented supply chain visibility systems would yield information which could be used to gauge what are common successes, disappointments or failures. The scorecard evaluation instrument proposed by McIntire (2014) would be a suitable framework upon which to build such research.

**Recommendations for the Industry**

The research has revealed that many of the challenges faced by practitioners are common. It is likely that the industry as a whole would benefit from the development of a standardization of supply chain data and processes. The Internet of Things and cloud computing offer an opportunity for increased collaboration and data sharing capabilities. A unified approach to the realization of these capabilities would potentially allow for the maximum value to be derived. The feasibility of such a collaborative approach is difficult to gauge. Organizational willingness to share data presents a significant obstacle. Protection of intellectual property is a concern for service providers. With competing logistics service providers offering visibility tools aimed at adding value and increasing competitive advantage, achieving industry-wide standardization would be a difficult process to navigate. There is however, precedence for success in such initiatives with large scale global standardization having been achieved for barcode and Global Trade Item Number (GTIN) adoption.
Appendix A

Reflections on Learning

There were a number of reasons why I decided to undertake an MBA. In my professional career I had begun to transition from more technically oriented roles into roles which were more related to project management. Having looked at a number of MBA course outlines, I saw that many of the areas which I felt I need to improve my understanding of were covered. In particular, areas such as financial analysis, international management, business strategy and project management were of interest. I acknowledged that it would be both an interesting and highly challenging undertaking. I had already experienced the challenge of combining further education with working full-time, having completed an honours degree in computer science between 2005 and 2009, so I was aware of the road ahead and the level of discipline and commitment required to be successful.

MBA Program and Dissertation Process

Because my primary degree was in Computer Science and was very practical and technical in nature, the academic slant of the MBA introduced an unexpected challenge. The rigorous process of critically reviewing and then synthesising academic literature, was a skill-set I quickly had to acquire and develop. The importance of the dissertation was introduced from the very beginning of the MBA program. Research methodology modules in year 1 and in year 2 provided a solid academic foundation and ensured that the dissertation was present in the consciousness of the student from the outset of the course. Progressive milestone deliverables for these modules meant that the dissertation topic was undergoing continuous development. In my own case, the general topic was seeded from early on in the course. Because of my professional interest, supply chain visibility was an obvious subject matter choice. The application of Internet ofThings technologies to supply chain visibility always featured strongly as an area which I was eager to explore. Early iterations of the research proposals had a strong focus on exploring that it as the major focus as it combined my previous qualification in computer science and my professional interest. As I began to explore the subject, I became more conscious of the fact that the concept of supply chain visibility itself was somewhat ill defined. It became a prominent research objective to explore this, because in order to attempt to address a challenge using technology, it is first necessary to understand the challenge itself. It also became apparent that many supply chain visibility challenges are actually directly related to the underlying technologies. This was an unexpected outcome of the research and one which triggered many potential avenues for further research as outlined above.
From meeting other MBA graduates and preforming some superficial research, it appears that different academic institutions favour different approaches to MBA programs. Some institutions like DBS favour a more academic approach to the capstone project with an emphasis on academic style research based on theory and peer-reviewed literature. Others favour a more practical approach preferring to have students perform a consultation or business strategy related project.

I'm sure there is a substantial topic in evaluating the advantages and disadvantages of various approaches. It is my opinion that the overall program at DBS possessed a good blend of academic and practical projects and assignments. Perhaps MBA program students could benefit from the addition of some more practical elements such as workshops on management skills, leadership skills, presentation skills or sales techniques. Ultimately, the most important things that I will take away from this program are the importance of critical thinking, the increased level of self-awareness I have attained and the friendships I have developed with my fellow MBA students.

**Researcher Learning Style**

The researchers own preferred learning style influenced the overall approach to the dissertation. On the VARK learning style test I scored highly as visual and kinaesthetic, while on the Honey and Mumford adaptation of the Kolb test I scored highest as a reflector, lowest as an activist and equally as a theorist and pragmatist. These results were interpreted as an indication of suitability to analysis of qualitative data since the reflector learning style favours being able to take time to think and process information collected or observed (Honey and Mumford, 1992).

![Learning Styles and Steps](Fig. A 1 Learning Styles and Steps (Swailes and Senior, 1999))
Appendix B

Ethical Considerations

There are a number of considerations in relation to ethical behaviour during research. While organisations typically have their own specific guidelines, which vary depending on the nature of the organisation or the research, there are some common principles. The principles below are from “The Belmont Report” (1979) and are referenced in the “Dublin Business School Ethical Guidelines for Research with Human Participants & Procedures for Ethical Approval” document (DBS, 2012).

- Respect for Persons – Respecting individuals rights including their right to participate in the research
- Beneficence – Minimising the risk of harm to participants
- Justice – Balancing the costs and benefits of research and participation in research.

The report offers guidelines in considering how to operationalise these principles under the following headings.

Informed Consent

This means that individuals can decide whether they wish to participate in the research. It also suggests that, where possible, the individuals should be provided with as much information prior to the research, without impacting the outcome of the research.

For my data collection, the interviewees were provided with the Information Sheet and Consent Form (Appendix C), which outlines the purpose of the dissertation and a summary of the objectives of the research along with a description of the procedure. They were also provided with a copy of the Interview Questions Form (Appendix D) approximately 48 hours in advance of the interview, to allow them some time to consider the topics. The candidates were given the option to withdraw at any time. The questionnaire was distributed in online format which included on the front page a brief overview of the research and an assurance of the confidentiality of the collected data along with the option to opt out at any time. The survey participant was given the option to continue by accepting that they had read and understood the overview and that they were taking part voluntarily, or to exit the survey.
Assessment of Risks and Benefits

Potential risks and benefits to the participants should be assessed. Where risks are identified they should be evaluated to see if the potential benefits are justified. Procedures should be put in place to minimise exposure and provide support. In the case of my research there was no situation where participants are exposed to any form of risk.

Selection of Participants

According to the Belmont Report the selection of participants should be handled using fair practices. My research requires that participants are employed by Life Science or related organisations and have knowledge of supply chain management or related activities. Potential participants will be contacted with details of the research and asked if they wish to participate.

The DBS ethics process outlines four categories of research which require specific ethical approval. My research falls outside those categories, so I have completed and submitted only the ethics review form.

The DBS Ethics Review form is included in the Appendix of this proposal. It has been completed to the best of my ability with the information I currently have access to.
Appendix C

Information Sheet for Participants

PROJECT TITLE: Supply Chain Visibility Dissertation

You are being asked to take part in a research study on the topic of supply chain visibility and the potential for technology to address challenges in that area. The study focusses on the life science industry in Ireland and is being carried out as the capstone project for a Master's Degree in Business Administration.

WHAT WILL HAPPEN

In this study, you will be asked to take part in a face to face or telephone, semi structured interview where you will be asked to share your thoughts and expertise on the following topics. The interview will be recorded.

- Understanding what is meant by supply chain visibility.
- Key supply chain related challenges facing life science organizations.
- The potential role of Internet of Things technology in addressing those challenges.
- Possible barriers which may be preventing Internet of Things from addressing supply chain challenges.
- Benefits of the application of Internet of Things to improving the integrity of cold chain logistics.
- Explore potential additional applications for data that is being collected by these types of systems.

TIME COMMITMENT

The interview should take no more than 45 minutes to complete.

There may be some follow up required to clarify points, but that should be minimal and be possible to quickly handle over email or by phone.

PARTICIPANTS’ RIGHTS
You may decide to stop being a part of the research study at any time without explanation required from you. You have the right to ask that any data you have supplied to that point be withdrawn / destroyed.

You have the right to omit or refuse to answer or respond to any question that is asked of you.

You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome. A full de-briefing will be given after the study). If you have any questions as a result of reading this information sheet, you should ask the researcher before the study begins.

CONFIDENTIALITY/ANONYMITY

The data I collect will not contain any personally identifiable information about you. Interviewees will be referred to as IV 1, IV 2, etc.

The research findings may be used as presentation material at industry conferences and may be published on the DBS website or in other publications. Neither you nor your organization will be identifiable by the data contained in the final paper or any material derived from it.

FOR FURTHER INFORMATION

My supervisor, Dermot Boyle will be glad to answer your questions about this study at any time. You may contact my supervisor at dermoth@hotmail.com
Informed Consent Form

Project Title: Supply Chain Visibility Dissertation

Project Summary:

In this study, you will be asked to take part in a face to face semi-structured interview where you will be asked to share your thoughts and expertise on the following topics.

- Understanding what is meant by supply chain visibility.
- Key supply chain related challenges facing life science organizations.
- The potential role of IoT technology in addressing those challenges.
- Possible barriers which may be preventing IoT from addressing supply chain challenges.
- Benefits of the application of IoT to improving the integrity of cold chain logistics.
- Explore potential additional applications for data that is being collected by these types of systems.

By signing below, you are agreeing that: (1) you have read and understood the Participant Information Sheet, (2) questions about your participation in this study have been answered satisfactorily, (3) you are aware of the potential risks (if any), and (4) you are taking part in this research study voluntarily (without coercion).

__________________________________________
Participant Name (Printed)  Participant signature

__________________________________________
Student Name (Printed)  Student signature

___________________________
Date
Appendix D

Interview Questions

Supply Chain Visibility

Please describe what the term "supply chain visibility" means to you?

Challenges

Does your organization face any current challenges specifically around supply chain visibility (SCV)? [Yes / No] Please describe them.

What are the biggest SCV related challenges you (or your organization, or industry) currently face?

[This question may have been answered from the initial challenges question. / Probe further.]

Are there specific challenges which have the most significant financial impact?

[This question may have been answered from the initial challenges question. / Probe further.]

Technology

Does your organization currently use any technology (software or hardware) in order to enhance SCV? [Yes / No] Please describe them.

Do your logistics service providers give you tools that enhance supply chain visibility? [Yes / No] Please describe them.

Are you familiar with the term Internet of Things? [Yes / No]

[If no, provide the interviewee with a brief explanation.]

What is your understanding of Internet of Things?

Is your organization currently using any Internet of Things technology to address supply chain visibility challenges? [Yes / No] Please describe them.

Are you aware of any initiatives underway or upcoming?

[This question may already have been answered from the initial technology question.]
Appendix E

Survey on Supply Chain Visibility

OVERVIEW

You are invited to take part in a survey on the topic of supply chain visibility, supply chain visibility challenges and the potential for technology to address challenges in that area. The study is focused on the life science industry and is being carried out as the final project for a Master’s Degree in Business Administration at Dublin Business School.

CONFIDENTIALITY

This is an anonymous survey and the data collected does not contain any personally identifiable information or IP address information. You may opt out or discontinue the survey at any time.

If you have any questions, please contact me at 10352788@mydbs.ie

1. Select "Agree" below to indicate that:
   • you have read the above information
   • you voluntarily agree to participate
   • you are at least 18 years of age

☐ Agree

☐ Disagree (end the survey)

2. Which of the following best describes the area in which your organization operates?

☐ Pharmaceutical

☐ Bio-technology

☐ Medical Devices

☐ Logistics / Distribution

☐ Other
3. Which of the following best describes the functional area in which you operate?

☐ Logistics / Distribution / Supply Chain

☐ Operations / Production

☐ Quality Assurance / Product Security

☐ Purchasing / Vendor Management

☐ Information Technology / Engineering

☐ Research & Development

☐ Sales & Marketing

☐ Finance & Accounting

☐ Other

4. Please evaluate the following statement.

Supply chain visibility in the life sciences industry is:

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<tr>
<th>Not Important</th>
<th>Slightly Important</th>
<th>Moderately Important</th>
<th>Very Important</th>
<th>Extremely Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

5. Please select which of the following definitions you think best describes supply chain visibility:

☐ The extent to which actors within a supply chain have access to or share information which they consider as key or useful to their operations and which they consider will be of mutual benefit.

☐ The identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events.
The awareness of, and control over, specific information related to product orders and physical shipments, including transport and logistics activities, and statuses of events and milestones that occur prior to and in-transit.

A process of collecting supply chain data, integrating it, extracting intelligence from it and using that intelligence to interrupt decisions in a cross-organizational supply chain oriented context.

6. Please evaluate the importance of the following types of supply chain visibility:

<table>
<thead>
<tr>
<th>Description</th>
<th>Not Important</th>
<th>Slightly Important</th>
<th>Moderately Important</th>
<th>Very Important</th>
<th>Extremely Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>The total view of all inventory regardless of location. (World as a Warehouse)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>A given product's life-cycle events. (Lot and Serial Number Tracking)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Whether or not inbound product will arrive on time. (Inbound Track and Trace)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The correct physical location of a supply chain entity? (GPS Tracking)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The status of a given object in the supply chain versus its expected status. (Status Visibility)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The capability to infer the correct action from a pattern of important facts. (Event Management)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
A view of competitor's supply chain(s). (Competitive Market)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Unsure</th>
</tr>
</thead>
</table>

7. Has your organisation implemented a supply chain visibility solution in the past 12 months?

☐ Yes

☐ No

☐ Unsure

8. Please select the most appropriate statement in relation to the data collected by the recently implemented supply chain visibility solution:

<table>
<thead>
<tr>
<th>No data is captured</th>
<th>Some data is captured but it is incomplete</th>
<th>All data is captured but the accuracy or quality is unknown</th>
<th>All data is captured and is high in quality and accuracy</th>
<th>Not applicable / Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

9. Please select most appropriate statement in relation to the data integration of the recently implemented supply chain visibility solution:

<table>
<thead>
<tr>
<th>Data remains in the capturing systems with no integration for later use</th>
<th>Data remains in the capturing system and can be manually integrated</th>
<th>Data is integrated and available but not using preferred methods</th>
<th>Data is integrated and available using preferred or easily adapted methods</th>
<th>Not applicable / Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
10. Please evaluate the following statement in relation to the recently implemented supply chain visibility solution:

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The data provided by the system supports important decision making processes</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

11. Please evaluate the following potential barriers to supply chain visibility:

<table>
<thead>
<tr>
<th>Not Significant</th>
<th>Slightly Significant</th>
<th>Moderately Significant</th>
<th>Very Significant</th>
<th>Extremely Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor definition of supply chain visibility requirements or deliverables</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Lack of availability of suitable technologies</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Poor integration of data between supply chain visibility systems</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Lack of standardization between supply chain visibility systems /</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
12. 'Internet of Things' refers to the interconnection of electronic devices allowing them to send and receive data.

Does your organisation use this type of technology to capture data about the identity, location, or status of product or orders in your supply chain?

☐ Yes

☐ No

☐ Unsure

13. Does your organisation use technology to give you real-time information about any of the following?

Please select all that apply.

☐ Quantity of inventory in local warehouse

☐ Quantity of inventory in remote (or 3PL) warehouse

☐ Physical location of product or orders in-transit (eg. GPS location)

☐ Environmental condition of product or orders in-transit (eg. temperature, humidity, etc.)

☐ Other
14. Please evaluate the importance of the following:

<table>
<thead>
<tr>
<th>Not Important</th>
<th>Slightly Important</th>
<th>Moderately Important</th>
<th>Very Important</th>
<th>Extremely Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowing the location of my orders while they are in transit.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Knowing the temperature of my orders while they are in transit.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

15. Please briefly outline a current supply chain visibility challenge faced by you or your organisation.


16. Imagine you have been given budget to implement a system to address a supply chain visibility challenge tomorrow. Please briefly describe the functionality of the system you would choose to implement.


17. Please add any additional comments you may have about supply chain visibility, supply chain visibility challenges or supply chain visibility technology.
Appendix F

The Supply Chain Visibility Scorecard Evaluation Instrument (McIntire, 2014)

Supply Chain Visibility Scorecard

How to Use the Scorecard:
1) For each visibility solution options, create one of these scorecards.
2) Add the list of business decisions which should be improved by supply chain visibility to the first column on the left.
3) After studying the solution design, and using the score guidelines provided, give each business decision a score for each metric.
4) Sum the scores by business decision and divide the sum by 24. This is the “fit ¾” for the solution as compared to the needs of the business decision, it is added to the column on the far right.
5) Average the fit percentages and add to the sheet the expected solution costs.
6) Plot the relationship between fitness percentage and solution costs and then eliminate any options which are strongly dominated.
7) The remaining options represent the frontier of tradeoffs between fitness and solution cost. Differentiating between these options requires assessing the organizations priorities.

Note: the scoring guide can be changed to provide more or less weight on certain metrics, as long as the same score guidelines are used by all evaluators and for all solution options.

Fig. F 1 Page 1 of 3 of an example supply chain visibility scorecard instrument (McIntire, 2014)
### Supply Chain Visibility Scorecard

#### Sensitivity

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No data is captured to support the target business decision</td>
</tr>
<tr>
<td>1</td>
<td>Some relevant data is captured, but is incomplete</td>
</tr>
<tr>
<td>2</td>
<td>All data is captured but the accuracy of the data is unknown or known to be low</td>
</tr>
<tr>
<td>3</td>
<td>Data is complete and consistently biased (i.e. low quality but predictable)</td>
</tr>
<tr>
<td>4</td>
<td>All data needed to support the decision is captured, complete, consistent, and measurably high in accuracy</td>
</tr>
</tbody>
</table>

#### Accessibility

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Data remains in the capturing systems with no attempt to integrate the data for later use</td>
</tr>
<tr>
<td>1</td>
<td>Data remains in the capturing systems, but processes allow them to be manually integrated for ad hoc tasks</td>
</tr>
<tr>
<td>2</td>
<td>The solution integrates all the decision relevant data, but not all of it is retrievable by decision makers</td>
</tr>
<tr>
<td>3</td>
<td>Data is integrated and available to the decision maker, but not using the methods they prefer</td>
</tr>
<tr>
<td>4</td>
<td>All relevant data is integrated and accessible by any relevant path the decision maker could use</td>
</tr>
<tr>
<td>5</td>
<td>All relevant data is integrated, accessible, and the approach to integrating data is easily adopted</td>
</tr>
<tr>
<td>6</td>
<td>All relevant data is integrated, accessible, and the integration approach is self-updating when confronting new data types or sources</td>
</tr>
</tbody>
</table>

#### Intelligence

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>There is no automated recognition from the solution that a business decision is needed</td>
</tr>
<tr>
<td>1</td>
<td>Sometimes there is recognition from the solution that a business decision is needed</td>
</tr>
<tr>
<td>2</td>
<td>The solution always knows that the business decision is needed</td>
</tr>
<tr>
<td>3</td>
<td>The solution’s approach to recognizing the need for a business decision is easily updated by users</td>
</tr>
<tr>
<td>4</td>
<td>The solution’s approach to recognizing the need for a business decision is self-updating</td>
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</table>

#### Decision - Relevance

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>The solution has no explicit input to this business decision</td>
</tr>
<tr>
<td>1</td>
<td>The solution is a required information source for the decision maker. A user decides how and when to make the decision</td>
</tr>
<tr>
<td>2</td>
<td>The solution is a required information source for the decision maker. The solution decides when the decision is taken and the user decides everything else</td>
</tr>
<tr>
<td>3</td>
<td>The solution offers a set of action alternatives based on the event; or</td>
</tr>
<tr>
<td>4</td>
<td>Narrows the selection down to a few; or</td>
</tr>
<tr>
<td>5</td>
<td>Suggests one action; and</td>
</tr>
<tr>
<td>6</td>
<td>Executes that suggestion if the human approves; or</td>
</tr>
<tr>
<td>7</td>
<td>Allows the human a restricted time to veto before automatic execution; or</td>
</tr>
<tr>
<td>8</td>
<td>Executes automatically, then necessarily informs humans; or</td>
</tr>
<tr>
<td>9</td>
<td>Informs the human only if asked; or</td>
</tr>
<tr>
<td>10</td>
<td>The solution decides everything and acts autonomously, with no notice given to the users</td>
</tr>
</tbody>
</table>

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Fig F 2 Page 2 of 3 of an example supply chain visibility scorecard instrument (McIntire, 2014)
Supply Chain Visibility Scorecard

<table>
<thead>
<tr>
<th>Visibility Solution Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Decision</td>
</tr>
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</table>

Estimated Total Cost: ________  Overall Fit %: ______________

Fig. F 3 Page 3 of 3 of an example supply chain visibility scorecard instrument (McIntire, 2014)
Appendix G

Alignment of Supply Chain Entities with Data Capture Technologies

The researcher sees a natural alignment between the supply chain entity hierarchy outlined by Francis (2008) and the data capture technologies of Auto ID and IoT in a way that broadly takes into consideration the physical attributes of the entities. Barcodes can be printed in very small sizes making them suitable for application to small products and components. In some cases, barcodes are formed using a technique known as direct part marking (DPM). Barcodes are practical up to the level of a shipment where barcodes are printed on labels applied to pallets, or other material handling units but not practical for applying to the side of lading asset. Passive RIFD tags can be applied to item level entities although their size and relative cost often means that they are more frequently applied to cartons, orders or encasements. Active RFID tags, being more expensive and physically larger than passive tags, make them impractical for many item level applications and more suitable for encasements, shipments or lading assets. IoT devices capable of communicating location and environmental data via the cellular network are widely available and overcome the necessity for dedicated reading or scanning infrastructure which barcodes and RFID require. These capabilities make it possible for actors to have information about the identity, location, and state of an entity at stages of the supply chain when that entity is located outside the normal system boundaries of those actors. The hardware which enables this functionality typically means that the devices are more expensive and relatively larger than active RFID tags. With this in mind the devices are less suitable for small item level tracking and more suitable for orders, encasements, lading assets or vehicles. A 2014 IEC whitepaper notes the application of IoT based WSNs to supply chain activity, "tracking of goods at least at a pallet level is required. The pallet (or other packaging unit) thus becomes the "sensor" for measuring the flow of goods, [along with] a combination of multiple wireless technologies (GPS, RFID, WLAN, cellular)" (International Electrotechnical Commission, 2014).

By mapping the entities to Auto ID and IoT technologies we can describe a potential framework for standardizing the data structure of information relating to the identification of supply chain entities. Adding supplementary data made available by the technologies, such as quantity, location and state increases the information relating to the dimensions of supply chain visibility as identified by Francis (2008) and Papert et al (2016). Finally, by having a defined standard for
integrating the data or making it accessible through cloud computing systems, the final dimension of availability can be achieved.

![Diagram](image)

Fig. G 1 Adapted from Entity Hierarchy Francis (2008)
References


Akad Colak, E (2014) ‘The ongoing potential of RFID as an alternative to 2D barcode in pharmaceutical industry’ Dublin Business School


Sun, C. (2012) ‘Application of RFID Technology for Logistics on Internet of Things’ 2012 AASRI Conference on Computational Intelligence and Bioinformatics; 107-111


