Is Ireland ready to let robots take the wheel transporting freight?

Team 8

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Abstract

The last number of years is showing the convergence of different technological, economical, societal and political forces. Together they appear to be influencing a trend towards increasing level of autonomous operation in the area of transport in general and cars and trucks in particular. This trend may lead to fully autonomous vehicles being permitted to operate on public roads at some point in the future. Some commentators have argued that the road haulage industry will be one of the early adopters of this new technology as it has characteristics that make it more suitable for automation as opposed to the passenger transport sector. This dissertation will use a multimethodology approach drawing upon Mingers multimethodology framework and aligning it with Cameron’s 5 P’s which will form the instructions on how to proceed with each phase of research. Each phase will progress to a greater understanding of the current perception of AV within the freight industry, future developments and the readiness of Ireland to adopt this new technology.

As it stands, the chosen framework may not appear to be a fully realised interpretation of multimethodology. Nevertheless, it provides a sound set of guidelines to expand the research by including other methodologies in future developments.

The two methodology actions that were chosen for the dissertation were literature review and semi-structured interviews.

In conducting the review the team felt that the best way to present a coherent and instructive picture was to provide as clear a description as possible of the different technologies involved, the background to their development and how they are being implemented in the world today. This would range from the emerging area of autonomous vehicles to the current use of on-truck information systems. In order to provide a rich description the review would need to deal with the legal aspects and touch on the possible wider implications for the road freight industry, government/policy makers, wider economy and society which have a heavy dependence on the industry.

The semi-structured interviews were conducted with member of management in the Irish Road Haulage industry who hold senior roles in their organizations. The chosen candidates are key members within this sector. Their peers regard them as experts in the industry. The focus of the research was to seek the industry knowledge from expert policy makers to answer the research question defined by the themes that were explored to support the analysis of the research topic; Technology, Applications, Social and Economic Aspects and Policy and Legal Aspects.

The dissertation provides conclusions in each of the different themes and it gives a final conclusion on Ireland readiness to embrace AV technology in this industry. During the research of this dissertation it was found that there are elements of AV technology in the freight industry. These technologies are to assist the drivers and increase efficiency in the management of the industry operations. However, no evidence was found that shows Ireland is ready to embrace such technology in the road freight industry. The findings and analysis of the literature review and semi-structured interviews shows Ireland is not in a position to introduce such technology and so the answer to the research question is no.
Acknowledgments

The team would like to acknowledge the support of our family, friends and colleagues whose continuous support, understanding and patience during this time has been crucial for us to complete our dissertation.

To Ms. Diana Wilson, Project Supervisor, for her constructive guidance and time effort she put into the project to help us throughout the process.

To Mr. Simon McGinnes, Course Co-ordinator, for the guidance and advice.

To all the participants who took part in the interview process, their input was invaluable to our studies.

We would like to give a special mention to Noel Ebbs, Caridad Cruz, Patrick Enright and Mark O’Brien. Their understanding and (incredible) patience has been invaluable for the completion of our dissertation.
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Declaration

This dissertation is submitted to Trinity University of Dublin in partial fulfilment of the requirements for the degree of B.Sc. (Hons) Information Systems.

We hereby declare that the work carried out in this dissertation is entirely our original work and has not been previously submitted for a diploma or degree at this or any other university.

We agree that the School of Computer Science and Statistics, Trinity College Dublin may publish this report electronically and lend or copy this dissertation upon request.

Leidy Romero Cruz

Mainard Gallagher

Jennifer Inglis

John Lohan

Date: 29th March, 2015
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<th>Meaning</th>
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<tbody>
<tr>
<td>ACC</td>
<td>Adaptive Cruise Control</td>
</tr>
<tr>
<td>ADOSE</td>
<td>Reliable Application specific Detection of road users with vehicle On-board Sensors</td>
</tr>
<tr>
<td>AEI</td>
<td>Automatic Equipment Identification</td>
</tr>
<tr>
<td>AV</td>
<td>Autonomous Vehicles</td>
</tr>
<tr>
<td>AVI</td>
<td>Automatic Vehicle Identification</td>
</tr>
<tr>
<td>C-ITS</td>
<td>Cooperative Intelligent Transport Systems</td>
</tr>
<tr>
<td>CITYMOBIL</td>
<td>Project focused towards Advanced Road Transport for the Urban Environment</td>
</tr>
<tr>
<td>COM2REACT</td>
<td>Co-operative Communication System to Realise Enhanced Safety and Efficiency in European Road Transport</td>
</tr>
<tr>
<td>COMPANION</td>
<td>Cooperative Mobility Solution for supervised platooning</td>
</tr>
<tr>
<td>COOPERS</td>
<td>Co-operative Networks for Intelligent Road Safety</td>
</tr>
<tr>
<td>CVIS</td>
<td>Co-operative Vehicle Infrastructure Systems</td>
</tr>
<tr>
<td>Daimler AG</td>
<td>German company producer of premium cars and manufacturer of commercial vehicles</td>
</tr>
<tr>
<td>DG MOVE</td>
<td>Directorate-General for Mobility and Transport</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>eCall</td>
<td>Initiative with the purpose to bring rapid assistance to motorists involved in a collision anywhere in the European Union</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>GEONET</td>
<td>Geo-addressing and geo-routing for vehicular communications</td>
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<tr>
<td>GPS</td>
<td>Global Positioning Systems</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile communication</td>
</tr>
<tr>
<td>HGV</td>
<td>Heavy Goods Vehicle</td>
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<td>ICT</td>
<td>Information Communication Technology</td>
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### List of Abbreviations

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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>IDIADA</td>
<td>Technology services company specializing in product development for the international automotive industry</td>
</tr>
<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>IoV</td>
<td>Internet of Vehicles</td>
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<tr>
<td>IPv6</td>
<td>Internet Protocol version 6</td>
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<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>ITETRIS</td>
<td>Integrated Wireless and Traffic Platform for Real-time Road Traffic Management Solutions’</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transport Systems</td>
</tr>
<tr>
<td>LIDAR</td>
<td>Light Detection and Ranging</td>
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<tr>
<td>MMR</td>
<td>Mixed Methods Research</td>
</tr>
<tr>
<td>MOS</td>
<td>Management and Organizational Science</td>
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<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PROMETHEUS</td>
<td>Program for European Traffic with Highest Efficiency and Unprecedented Safety</td>
</tr>
<tr>
<td>QUAL</td>
<td>Qualitative</td>
</tr>
<tr>
<td>QUAN</td>
<td>Quantitative</td>
</tr>
<tr>
<td>REACT</td>
<td>Realise Enhanced Safety And Efficiency In European Road Transport</td>
</tr>
<tr>
<td>Rpms</td>
<td>Revolutions per minute</td>
</tr>
<tr>
<td>SAFESPOT</td>
<td>Co-operative Systems for Road Safety: Smart Vehicles on Smart Roads</td>
</tr>
<tr>
<td>SARTRE</td>
<td>Safe Road Trains for Environment</td>
</tr>
<tr>
<td>SCANIA</td>
<td>Swedish company specialising in the manufacture of heavy trucks and buses</td>
</tr>
<tr>
<td>SENSE</td>
<td>Smart Embedded Network of Sensing Entities</td>
</tr>
<tr>
<td>TARDEC</td>
<td>Tank Automotive Research Development and Engineering Center</td>
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Chapter 1: Introduction

The transportation of goods is a fundamental aspect of commerce and production. The goods may be transported using different modes such as by sea, air, rail or road or combinations of these which together make up a logistics chain. Of the four modes the most indispensable is road as in most cases it provides the first and last links in the chain from vendor to customer.

Statistics obtained from the Eurostat’s database illustrates the dominance of road freight transport across Europe but it is most apparent in Ireland with Eurostat data from 2012 showing 99.1% of freight being transported by road (Eurostat, 2012). Transport of freight by road is expected to retain its importance within the EU over the coming decades (Enei, Riccardo, 2010).

1.1 Background

A report from the Organization for Economic Co-operation and Development (OECD) in 2012 describes the amount of freight transported by road as increasing massively over the last 50 years. The report states that there are many reasons for this huge increase varying from the flexibility provided by road transport, the expansion of the road network, the innovation of the shipping container, globalization and modern manufacturing/logistical practices such as the Just-in-Time model. This results in lower inventory levels and fewer, larger warehouses which have increased the reliance on transport links. The previous 30 years have seen major developments in the design of heavy freight trucks that has resulted in greater cargo haulage capacity and better fuel efficiency and requiring less physical effort from the driver (International Transport Forum, 2012).

Over the last 15 years there has seen the introduction of Information and Communication Technology (ICT) systems into trucks with the aim of increasing productivity and fuel efficiency. It has been argued that the coming years will see a revolution in smart connected technologies which will enable new levels of automation (Porter & Heppelmann, 2014). These new technologies have the potential to transform many sectors including the automotive and logistics industries.

Autonomous Vehicles (AV) technology is not a new concept within the automotive industry. Europe’s contribution to autonomous driving research goes back to over two decades ago with their project PROMETHEUS. In 1995 the team toured from Munich, Germany, to Denmark at up to 175 km/h with around 95% autonomous driving. Autonomous Technology has continued to develop since. The Defence Advanced Research Projects Agency (DARPA) organised a first Grand Challenge for autonomous off-road ground vehicles in 2004 followed by a second challenge in 2005 and a third challenge taking place in 2007. Car manufacturers and countries are investing heavily in research and development projects of AV, investigating its impact on various topics such as economies through to implementation Ziegler et al. (2014).

Testing of driverless vehicles on the roads is becoming a reality in different countries around the globe. North America was the first country to introduce legislation to allow testing of autonomous vehicles on public roads. Other countries such as Germany and Sweden have also reviewed their legislation regarding autonomous vehicles. The UK has also started to look into making changes to legislation; the UK Transport Minister announced that the government will publish a Code of Practice in spring 2015 for those wishing to test driverless vehicles on UK roads (UK Department of Transport, 2014).

Today, having fully autonomous vehicles on the roads is not a vision but a real possibility. Cars manufacturers have announced and showcased different types of autonomous vehicles prototypes with some of them operating under trial on the roads. Nevada, U.S. A. was the first state to put in place a law to allow autonomous vehicles on the road. This law took effect in March, 2012. Following
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this, Florida and California U.S.A. also approved laws to enable autonomous vehicles on the roads in September, 2012 (Florida Highway Safety, 2014).

In September 2013, Japan legalised autonomous vehicles on the road, issuing the first license to Nissan (Charlton, 2013). The UK made its first announcement in 2013 stating the government was open to support research in autonomous vehicles technology. This was followed in July, 2014 when the UK announced that autonomous vehicles would be allowed on the roads in January 2015 (BBC News, 2014).

The freight transport industry is not lagging behind the world of autonomous vehicles transport. Large companies involved in this industry have taken the lead to implement autonomous systems in haulage vehicles. Komatsu was the pioneer in the mining industry, introducing the technology in 2008. Other big companies in the industry have followed suit such as Caterpillar. Another area where AV technology is being explored is road trucks on public roads. The EU funded the Safe Road Trains for Environment (SARTRE) project, which started in 2009. The car manufacturer participating in the SARTRE project was Volvo. The experiment consisted in forming a road train or platoon, with one lead truck at the front, followed by another truck and three Volvo cars (SARTRE, 2012).

This dissertation will give an overview of current research being performed into autonomous freight vehicles and the technologies that they contain. It will also attempt to give the reader some idea of the complex array of issues, implications and stakeholders that will surround the introduction of autonomous freight vehicles onto public roads in a country.

1.2 Research question

After engaging in initial research and analysis in the freight transport industry the research question was formulated. Early investigations indicated that Ireland has not yet taken the first steps towards automation in the road freight industry. The primary aim of this document will be to answer the question:

**Is Ireland ready to let robots take the wheel transporting freight?**

The dissertation will explore autonomous driving within the road freight industry to Ireland’s position regarding AV with focus on the following themes: Technology, Applications, Social and Economic Aspects and Policy and Legal Aspects. By analysing worldwide developments of each of these areas in the AV field, it can be assessed where Ireland currently is and what will need to be done to introduce this technology into the country exploring each of these themes. Through interviews with key influencers and policy makers of the haulage industry within Ireland the dissertation will gauge whether the Irish haulage industry is ready to embrace such technology as well as cover limitations and areas for future research.
1.3 Dissertation Structure
This research project follows the structure below.

Chapter 1 Introduction
The research question is defined as well as the themes that will be explored to support the analysis of the research topic: Technology, Applications, Social and Economic Aspects and Policy and Legal Aspects. The chapter also includes a background of the topic that will be researched.

Chapter 2 Literature Review
The section discusses the research of available literature incumbent to the research question to understand prior research conducted in this area. The literature is presented according and following the order of the four themes identified for the analysis of the research question.

As well as the main research question, the literature review explores other questions derived from the main topic that contribute to a more complete analysis of the subject.

Chapter 3 Research Methodology
This chapter will describe the methodology that was used to structure the dissertation. It will outline the methodology approach that was chosen to develop the framework. This section will detail the rationale for choosing such framework to answer the question “Is Ireland ready to let robots take the wheel transporting freight?”

Chapter 4 Findings, Analysis and Recommendations for Future Research
The chapter presents the findings from the literature reviewed and contains the analysis of the semi-structured interviews. It also presents recommendations for a future research as a new project to explore the introduction of AV in Ireland.

Chapter 5 Conclusions
This section summarises the main deductions drawn from the findings of the research. The summary will give an answer to the research question “Ireland ready to let robots take the wheel transporting freight?” A conclusion is drawn after analysing Ireland’s readiness in each of the areas identified in Chapter 1: Technology, Applications, Social and Economic Aspects and Policy and Legal Aspects. The chapter concludes with an overview of Ireland’s readiness for AV in the freight industry as well as recommendations for future research derived from the dissertations’ research findings.
Chapter 2: Literature Review

2.1 Introduction

Okoli and Schabram (2010) argue that literature reviews serve a variety of purposes; providing a theoretical background for subsequent research, learning the breadth of research on a given topic or answering practical questions by understanding what the existing research has to say on the matter.

Webster and Watson (2002) note that there are extra complexities in assembling a literature review in the area of Information Systems. The argument is that there is a need to draw on theories from a variety of fields due to the interdisciplinary nature of the subject. However despite this the literature review is the foundation of research in the field of Information Systems.

The approach taken in planning and implementing the review is fully described in Chapter 3. The analysis and interpretation of the findings of the review is provided in Chapter 4. The review was performed over the following five stages using the process described by Randolph (Randolph, 2009).

Problem formation: Following an initial exploratory review a list of questions were decided following discussion among the group. These were general questions such as; what research is being performed on autonomous freight vehicles? Who are the main players?

From these questions a list of topics was drawn up which was divided up among the team.

Data collection: Searches for relevant papers were performed using Stella Search, Google Scholar and online libraries such as ScienceDirect. The scope of the searches was mostly confined to the last 10 years. This number was arrived at by adopting the search strategy of Sternberg et al. (2014) who reviewed the literature to analyse the use of ICT in haulage companies. The bibliographies of recent books on automation were also used to find influential papers relating to the subject. Those books which were helpful but are not directly cited in the review are listed in the bibliography section of the dissertation. For some topics such as the Irish Road Haulage Industry it was difficult to find up to date research. These areas were noted and are included in Chapter 5 under the Recommendations for Further Research.

Data Evaluation: Data relevant to the subject was extracted and tracked in spreadsheets.

Analysis and interpretation: In this stage the chosen data was analysed. This is covered in Chapter 4.

Public presentation: At this stage the data was chosen which would be included in the final report.

2.2 What is an Autonomous Vehicle (AV)?

“An autonomous car, also known as robotic or informally as driverless or self-driving, is an autonomous vehicle capable of fulfilling the human transportation capabilities of a traditional car.” (Chakraborty, 2013).

The concept of autonomous or driverless vehicles is in existence since the early days of automobile. “In 1925, Time magazine carried an article about a car that cruised New York City streets without a driver, guided by radio control. The General Motors Futurama exhibition at the 1939 New York World’s Fair depicted a future of self-driving cars by the industrial designer Norman Bel Geddes.” (Stenquist, 2014)
Lutin, Kornhauser and Lerner-Lam (2013) defined four basic elements categories in autonomous vehicles technologies:

Sensors Technology: “... includes a variety of such hardware as multiple video cameras for daylight conditions, forward-looking infrared sensors for night conditions and detection of humans and animals, radar for measuring range and velocity, global positioning systems (GPS) to determine location, accelerometers and gyroscopes to detect changes in speed and direction and light detection and ranging (LiDAR) that employs spinning lasers and photoreceptors to create a three-dimensional model of the immediate environment.”

Mapping Technology: “... typically uses coordinate files of points and line segments representing streets, origin and destination addresses and other features, including digital aerial photography, ground-level imagery of roadway features, traffic control devices and obstacles. Mapping also may include stored terrain models created with LiDAR.”

Perception Technology: “includes the set of software processes that fuse data from the various sensors, compare it with stored mapping and determine how the vehicle will react to the various inputs. Perception includes determining and maintaining the vehicle's position within the traffic lane and with respect to other moving vehicles, monitoring and reacting to traffic control devices, detecting and reacting to pedestrians and other obstructions in the vehicle's path, keeping track of the vehicle's location with respect to the map and monitoring and reacting to the forces acting on the vehicle. Other functions include monitoring the health of the vehicle and its automated systems.”

Communications Technology: can operate vehicle to vehicle (V2V) and vehicle to infrastructure (V2I). V2V communication can allow vehicles to exchange information about their position and movement intentions, allowing other vehicles to anticipate and respond to manoeuvres. V2I communications can allow vehicles to communicate with traffic control devices and allow the exchange of mapping data between stationary sources and vehicles.

Autonomous vehicles have the ability to: Function from start to finish on public roads without human interaction; monitor surrounding conditions throughout the journey; analyse the environment and make the most efficient decision on best route to take; move from place to place depending on human demand; think and react to unexpected situations the same way if not quicker and better than human beings and Improve performance over time by learning from the scenarios that they are in place (Chakraborty, 2013).

2.3 AV Technology

The latest advancements in autonomous vehicles technology reveal great potential for the freight industry. The evolution of this technology could represent benefits for freight transporting companies in key areas such as reduced labour costs, increased safety and fuel efficiency (Martin, 2014).

The National Highway Traffic Safety Administration (NHTSA) defines five different levels of vehicles automation for better understanding of automation of which they are currently working on:

Level 0 – No-Automation: where the driver is in complete control of the vehicle. The vehicle has certain support systems proving warnings in several scenarios, for example blind spot monitoring and lane departure warning. However the vehicle does not have control over steering, braking, or throttle.
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**Level 1 – Function-specific Automation:** where the driver has overall control but can chose to yield certain control to the vehicle. If multiple functions are automated, they operate independently from one another, for example steering or braking/throttle controls, but not both. With this level of automation the driver cannot leave the operation of the vehicle to the vehicle itself.

**Level 2 – Combined Function Automation:** where the driver maintains responsibility for monitoring the road and safe operation. This level of automation involves at least two primary control functions designed to work in conjunction to replace the driver’s control of those functions. The driver can yield primary control in some driving situations. The vehicle can give up control without warning in advance so the driver must be ready to take control of the vehicle at all times safely and in short notice. With this level of automation the driver can have his or her hands off the steering wheel as well as foot off the pedal simultaneously; however he or she must constantly monitor the road.

**Level 3 – Limited Self-Driving Automation:** where the driver can yield total control of the safety-critical functions under specific conditions. During the automated driving mode the vehicle would have the main responsibility of driving and monitoring the conditions. The vehicle can determine if the system can no longer support automation and retrieve control of the vehicle to the driver with appropriate transition time for the driver to take control. The driver is not required to constantly monitor the road.

**Level 4 – Full Self-Driving Automation:** where the driver is not expected to take control of the vehicle at any stage throughout the trip. The driver will only provide destination or navigation input, including occupied and unoccupied vehicles. The automated vehicle system will have full responsibility to perform all safety-critical driving functions and monitor of the road.

Martin (2014) describes that at present vehicle automation in trucks would probably fall under Level 1 automation. This is because of the existing automated functions in trucks that support the driver. However the driver can still chose to manually operate such functions. An example of this can be found in Volvo’s Advanced Transmissions for Trucks, to maintain low rpms at highway speeds. The advanced transmissions also engage in advanced torque management, to maintain lower torques for fuel efficiency. However the drivers can switch to high torques when desired. Some truck like Volvo’s high-end models are equipped with Level 2 automation elements. For example Advanced Stability Control for Trucks which will lower the torque and apply brakes to individual wheels simultaneously to avoid rollovers and jack knives. As well as this, lane departure warning systems track road markings and can warn the driver if it detects unintentional drift. Finally, trucks can now have radar that provides drivers with warnings if they are too close to a vehicle ahead of them and further de-throttle and apply the brakes if necessary.

The section below will provide an overview of some of the technological parts that allow vehicles to drive autonomously and or provide drivers with warning alerts. Some of these autonomous technologies can be found but are not limited to trucks.

### 2.3.1 Adaptive Cruise Control (ACC)

This is a system that uses either radar or lasers to track vehicles in front to maintain a safe distance. The vehicle is able to adjust its speed to accommodate changes in traffic conditions activating automatic braking and acceleration. ACC enables speed synchronization among vehicles and reducing the number of sudden accelerations. It assists with lane transition, decelerations and reduces accidents. In the event of a possible collision the vehicle decelerates and comes to a complete stop. The driver’s tasks are considerably reduced under regular traffic circumstances because control of the distance to the preceding vehicle, via both brake and throttle action, is done automatically (Weinberger, et al., 2001)
2.3.2 Lane Departure Warning

When the vehicle is in motion, a video camera in the rear view mirror tracks the lanes markings on the road ahead. The system is in place if the driver becomes distracted or is tired. The on-board computers software detects the vehicles position within the lane and compares it with additional inputs taken from other components such as steering angle, brake and accelerator position sensors; it also takes into account whether the indicators are in use. If the vehicle leaves its lane without direct input from the driver an audio alert is sounded or haptic feedback is activated by vibrating the seat. The vehicle will display the possible reasons of the alert on the dashboard. If a self-driving car cannot decipher missing lane markings or lane lines covered by snow, an alert will sound to warn the driver to take control of the steering wheel. Over time the data will be incorporated into GPS systems to give drivers advance warnings of problems ahead (Richards, 2014).

2.3.3 Collision Avoidance System

The earliest use of Collision Avoidance System was the Mercedes-Benz Pre-Safe system in the 2003 S-class sedan (Fuller, 2009). The system used sensors to measure the car's steering angle and acceleration, but not its surrounding environment – actions such as pre-tensing of the seat belts, automatic sunroof closing and raising of reclined seats were triggered during any emergency manoeuvre. This system mitigates or avoids a collision event. It provides the driver sufficient time to take appropriate actions to correct the vehicle trajectory. An array of sensors determines how close the vehicle is to other vehicles around it. It can decide how much speed is needed to be reduced while going around bends on the road. It is possible that the sensors can communicate with sensors on other vehicles relaying information back and forth regarding potential changes in weather conditions and obstacles in the road.

2.3.4 Parking assistance

Intelligent Parking Assist System was first introduced by Toyota Motor Corporation 2004 in its hybrid Prius models. The car uses an intelligent parking system which means it can park itself using electronic sensors. The sensors judge its position and so allow it to avoid obstacles like other parked cars and kerbs. It integrated a parking space management system to assist drivers to park automatically by avoiding obstacles and other vehicles while parking. While the vehicle is in motion, at a speed of 20km or less, the sensor gauges appropriate space for the vehicle, based on its dimensions. When a sufficient space is available the driver is notified via the dashboard. The driver is alerted if the space is big enough for the car, too small or if it is a tight squeeze.

2.3.5 LIDAR

Light Detection and Ranging (LIDAR) sensors are used in autonomous vehicles as they offer a high level of accuracy, range and speed. LIDAR uses light in the same way a bat or dolphin uses sound waves and can bounce infrared light off everything within 200 feet to generate a real-time 3D map of the surrounding environment. The light beams are fired in all directions around the vehicle. Information is returned as raw data that the on-board computers interprets and initiates actions to avoid obstacles and to navigate safely.

2.4 AV Applications

As previously discussed Autonomous Vehicle Technology has been applied to different extents throughout the years. More recently, an increasing number of companies have announced their experimental trials on the roads.

Some of the companies that can be mentioned are: Google, by the latter part of 2014 the company’s self-driving car had already logged 700,000 on public roads (Johnson, 2014). BMW demonstrated its semi-autonomous capabilities Mid-2011, where the trip was completed without human
intervention. The company revealed a further project to test self-driving cars that will be carried out over the next two years in China. Mercedes unveiled the self-driving Mercedes-Benz Future Truck this January 2015 (Daimler Benz, 2014). In the same month Audi’s self-driving car completed its first long-distance test drive, from Silicon Valley, California to Las Vegas. The company plans to continue self-driving technologies and it is said to plan its next test trip from San Francisco to New York (Computerworld, 2014).

In contrast with cars, the application of autonomous vehicles technology in trucks is not as noticeable. To help answer the research question of this dissertation, the following section will explore the developments that can be found to-date in two of the industries that use trucks i.e. Haulage and Mining industry. The latter has been chosen as it was pioneer in exploring automation of their trucks for the future of their industry in 1996.

### 2.4.1 Mining Industry

The initial research showed that autonomous technology was already well established in the mining industry. A study was conducted by Accenture in 2008 on behalf of a major mining company with the aim of evaluating whether the use of autonomous vehicles would provide competitive advantage. The study found that the use of autonomous trucks provided real and possibly substantial benefits. The study described the challenges faced by mining companies such as limited qualified labour, difficult work environments and the need of lowering costs as there is limited price differentiation in the industry. The main aspects identified where autonomous technology could bring benefits to the mining industry were performance improvement, increase of workers safety and reduction of labour requirements (Accenture, 2010).

The first company to introduce autonomous technology into the mining industry was Komatsu, the mining and construction equipment manufacturer. In 2008, the Chilean mining company Codelco, introduced Komatsu’s autonomous trucks into one of its mines and it was the first company in the world to rely on fully autonomous trucks for mining. Since then several other major mining corporations have introduced Komatsu’s autonomous truck; Rio Tinto started using them in 2008, as part of their Future program. Following this a second major mining and construction equipment manufacturer, Caterpillar introduced the technology in Australia working with mining companies BHP Billington and Fortescue Metals Group. The third key player following this trend is Hitachi, the Japanese company started trials for its autonomous trucks in April 2014 (Engineering & Mining Journal, 2014).

It can be argued that the mining industry has been quick to see the business value in autonomous vehicles and has taken bold steps in adopting the technology as part of a strategy to bring the industry forward. The trials carried out by the different trucks manufacturers and mining companies involved introducing the autonomous trucks into actual working environments. The adoption of these changes shows that the mining industry is prepared to implement autonomous vehicles. Our research indicates a possible trend where the bigger players introduce the technology first. Statistics obtained show that BHP Billiton and Rio Tinto, Australia are the top two mining companies regarding market value in 2014 (Statista, 2014). As noted earlier these were among the first companies to implement autonomous vehicles in mines. Other companies may be waiting to see results of these changes in the bigger players before deciding to invest in the new technology.

### 2.4.2 Haulage Industry

The level of innovation in logistics and freight haulage has been described as less than that of other industries such as manufacturing (Wagner, 2008). On the other hand many papers such as Zeimpekis & Giaglis (2006), Perego et al. (2011) and Benza et al. (2012) show how freight haulage companies
are willing to invest in ICT and new technology when it is seen to provide business value allowing them to provide new services to their customers.

The literature review conducted by Perego et al. (2011) found that although the take-up of ICT in haulage companies appeared to be low operators seem to understand the importance of ICT technology and have clear views about what services to offer to their customers (Perego, et al., 2011). Benza et al. (2012) describes an ITS system specifically for transporting dangerous or hazardous goods (DG) which is used by fuel distribution companies to comply with the EU legislation concerning international carriage of dangerous goods by road; the ADR. Yoshimoto & Nemoto (2006) give a hypothetical example of a system incorporating Automatic Vehicle Identification/Automatic Equipment Identification (AVI/AEI) where a truck approaching a container yard is automatically identified and given permission to enter and told where to unload or pick up cargo.

It was difficult to find data on the type of ICT systems currently in use by Irish hauliers. Basic research of several of the larger Irish freight haulage companies was performed by viewing their web-sites for example Reynolds Logistics (Reynold Logistics, 2015) The research suggest a similar situation as described by Marchet et al. (2009) where in a survey of freight transportation industry in Italy it was concluded that the main functions of ICT systems are related to order tracking and proof of delivery. A report commissioned by Forfás; the advisory board for enterprise, trade, science, technology and innovation in Ireland described that ICT was having a positive impact on the Irish freight haulage industry but industry feedback suggested that the take up level was low compared to the UK. The report went on to say that while Irish hauliers were using ICT to keep track of drivers and loads there was little evidence that the technology was being used to make fleet management processes more efficient such as informing drivers making a delivery that another load was available to be picked up nearby. It was also mentioned in the report that the UK government was encouraging the greater use of ICT as part of a 10 year plan for a modern transport system (Aylward & O’Toole, 2007). In contrast a transport report from the Irish government for the period 2009-2020 discusses the transportation of goods but there is no mention of encouraging the use of ICT in the freight industry (Department of Transport, 2009).

The overall current state of the freight transport industry in Ireland also appears to be similar to the scenario as described in Marchet et al. that the transportation industry has become more competitive. This is reported to be due to reasons such as globalization and internationalization and secondly due to customers putting pressure on transport companies by looking for lower prices and higher service levels when choosing their providers. These last points are partly collaborated by Aylward & O’Toole who say that the Irish freight industry is fiercely competitive but also mention that the internationalization of road freight is not such a big issue in peripheral island nations like Ireland (Aylward & O’Toole, 2007).

An observation reported by Perego et al. (2011) which also may apply to the freight transport industry in Ireland is that it is companies with larger fleets that provide services in the areas of refrigerated, hazardous materials, high value or just-in-time are more likely to implement ICT systems with features such as automatic vehicle location or identification.

These ICT systems all represent some level of automation of existing business activities taking place in the freight companies. Increasingly the focus of these technologies is on driver centred activities; evidence has shown that the driver represents the largest or second largest cost associated with freight transport (Sternberg, et al., 2014).

On 22nd September 2014, the German commercial vehicles manufacturer, Daimler AG, introduced the “Mercedes-Benz Future Truck 2025”. The company revealed that the technology integrated into the design of this truck enables it drive completely autonomously, independent from other vehicles.
or a central control station. The demonstrations of Mercedes’ truck capabilities were revealed using prototype demonstration. The company revealed the tests were carried out at speeds of up to 80km and in realistic traffic situations in a controlled environment in a section of A14 motorway in Germany (Daimler Benz, 2014).

Logistics provider DHL opened a research and innovation centre in 2006. In 2014 DHL produced a research report on Self-Driving vehicles that investigated the ways that autonomous vehicles are being used today in warehouses and controlled open-air sites. It considers the implications of this technology for the future of the logistics industry when the technology is able to operate in open environments and on public streets. The company outlines how assisted highway trucking will benefit line haul transportation. Autonomous technology will act as enabler of faster and better reaction to dangers on the road. This will have the potential to reduce driver errors and avoid accidents. Trucks will stay in line, at a safe distance from the vehicle in front and comply with the speed limit or the maximum truck speed. However, even though the technology used in this case has autonomous elements, the driver will still be required for some functions, such as changing lanes, incorporating into traffic and leaving the highway (DHL Trend Research, 2014).

The DHL report states that the ultimate goal is full automation where the truck will be able to travel from origin to destination without the need for a human to perform any driving. The report goes on to say that truck convoys will be another possible application of AV that shows great potential for the area of long haul trucking. Multiple trucks will be connected through smart technology, actions performed by the driver in the first truck in line and every other truck that follows performs the same action in synchronization. In this case, it is described that when trucks are in convoy, the drivers of the following trucks could use this time to rest or perform administrative tasks such as preparing for the next delivery, which could potentially increase the drivers’ efficiency (DHL Trend Research, 2014).

The vehicle manufacturer Volvo has taken the lead in this area. The company was one of the first companies to carry out trials on public on truck convoys in Barcelona, Spain (DHL Trend Research, 2014). Volvo carried out the tests under the project SARTRE (Safe Road Trains for the Environment), funded by the EU, which was under research for three years between September 2009 and September 2012 (SARTRE, 2012). The SARTRE project has been further developed since, under the name of COMPANION with the objective to apply platooning in daily transport operations. More details of the project COMPANION will be covered further in this document.

2.4.3 Intelligent Transport Systems (ITS)

ICT technologies are also described as Intelligent Transportation Systems. The primary aim of Intelligent Transportation Systems from an ICT perspective is to integrate individual transportation elements and join them through the use of information and communication technologies into a single system (Ranaiefar, 2012). Pagano et al. (2013) describe how the current interconnection between different parts of the transport systems was identified by the EU commission as a weak point in the European Transport network in the action plan for the deployment of ITS in Europe and it was among the areas prioritized in directive 2010/40/EU Framework for the deployment of Intelligent Transport Systems in the field of road transport.

Alessandrini et al. (2014) argue that future automated freight transport vehicles will need an ICT infrastructure to operate safely and efficiently. The system would interoperate with the systems of logistics operators to manage the flow of freight transport data. The authors outline a scenario of an urban consolidation centre that would manage the dispersing of freight. Cargos would be delivered to the centre then shipped out to customers using light duty automated vehicles. The authors envision this system for urban last-mile distribution and argue that operating in a mixed environment would not be detrimental to its performance.
While a system like this might be suitable in a setting like an industrial park it is difficult to see it being effective in an urban setting in mixed traffic, the authors appear to be slightly over optimistic concerning the challenges that introducing automated freight vehicles will face. The DHL research paper Self Driving Vehicles in Logistics argues that the last mile of delivery is often the most difficult as it most likely will be situated in complex and dynamic environments such as congested urban areas (DHL Trend Research, 2014). This can be attested to by anyone who has seen HGV’s delivering goods to supermarkets in busy urban areas. However what the scenario outlined by Alessandrini et al. could represent is a possible first step for automated vehicles in moving away from the closed environments where they currently operate such as ports, airports and warehouses to partially open environments such as industrial or business parks.

Research shows that autonomous vehicles will need to communicate with each other and with intelligent transport technology in the road networks to operate efficiently and integrated. The European Road Transport Research Advisory Council (ERTRAC), published their Multi-Annual Implementation Plan for Horizon 2020 in March 2013. The report covers four road transport key areas: vehicles, infrastructure, logistical and mobility services and energy and resources.

The paper acknowledges how important it is to focus on road infrastructures for cleaner and quieter vehicles. The report describes the different areas the research and development would focus on to achieve sustainable long distance and urban transport. The main areas related to autonomous vehicles are enhanced lanes specifically dedicated for autonomous vehicles that will enable advanced driver assistance systems to be used most effectively allowing vehicles to be operated in platoons. It is argued that this will result in more efficient fuel usage with a corresponding lower carbon footprint (ERTRAC, 2013).

Another aspect of ITS discussed in the report is infrastructure telematics which will provide real time support to road users and road management controllers. In this scenario the vehicles will be communicating with smart technologies embedded into the road infrastructure. The road management controllers will be able to monitor traffic flow in real time. The report argues that the proposed improvements will provide the foundation for advanced systems such as assisted driving, platooning and autonomous driving.

One of ERTRAC’s main focuses is road safety. Road infrastructure is described to be one of the key factors to enable the development safer roads. ERTRAC’s discusses the main three areas to be integrated are: the road user, the vehicles and the infrastructure. The report highlights the importance of the human factor in road infrastructure engineering to achieve optimal safety to road users. To try and achieve the optimum road safety system the report discusses areas to focus such as: driver support for accident avoidance, human-machine interaction, integration of active and passive systems to enable crash avoidance or injury reduction in case of vehicles collision, safety of new vehicles types with the appropriate intelligent concepts, safety of vulnerable road users through safety systems and advanced alarm and tracking vehicle systems, among others (ERTRAC, 2013).

Looking at Europe’s approach to embrace ICT into an EU-wide Intelligent Transport System, it can be perceived that there have been many projects carried out under test environments to explore the application of autonomous technology in European roads and the benefits to be had as a result. A paper published in IET Digital Library “Is ICT mature for an EU-wide Intelligent Transport System?” describes a proposed advanced Intelligent Transport System infrastructure for Europe. It addresses existing scalability and inter-operability problems and focuses on next generation networks.

There are different projects that have contributed to the development of future ITS (Intelligent transport System) in the European Union. According to Pagano et al. (2013) the projects carried out are: Co-operative Vehicle Infrastructure Systems (CVIS), an experiment based in Berlin aimed to
develop more efficient co-operative systems and improve road safety. Co-operative Networks for Intelligent Road Safety (COOPERS), with the objective to showcase a system that connected vehicles and road infrastructure through wireless communication in real time, tested in four different test locations (the Brenner Corridor from Nuremberg to Verona; the Rotterdam-Antwerp corridor; the Berlin city highway and the French corridor from Chamonix to Valence and the Paris area). Geo-addressing and geo-routing for vehicular communications (GEONET): to introduce a networking system to be integrated into co-operative systems, the networking mechanism was coordinated by France. Smart Embedded Network of Sensing Entities (SENSE): to develop a system where different embedded devices co-operate through wireless connections, the system was tested in a realistic environment at International Airport Krakow. Reliable Application specific Detection of road users with vehicle On-board Sensors (ADOSE): to improve systems functionalities to enhance driver assistance systems. The concepts developed during the project were tested in Sicurezza test track, Italy (ADOSE, 2011). Co-operative Systems for Road Safety: Smart Vehicles on Smart Roads (SAFESPO): to promote dynamic coordination between vehicles and between vehicles and road infrastructure, demonstrated in Amsterdam, 2010. Co-operative Communication System to Realise Enhanced Safety and Efficiency in European Road Transport’ (COM2REACT): an improvement of the REACT system, which uses a central server to process all the vehicles data collected and produces recommendations for vehicles and information for the relevant authorities. The technologies developed for this project were carried out in Paris. Towards Advanced Road Transport for the Urban Environment (CITYMOBIL): to explore the introduction of advanced technologies to achieve a more effective urban transport system. The project was demonstrated focusing in three cities, Heathrow, Rome and Castellon. An Integrated Wireless and Traffic Platform for Real-time Road Traffic Management Solutions (ITETRIS): to evaluate the exchange of information between vehicles and between vehicles and infrastructure under realistic conditions. The simulation platform for this was developed in Germany.

For Ireland to embrace and introduce this innovative technology it is necessary to firstly understand what actions are required to follow in the direction of leading countries in this field. Ireland’s closest neighbour, the UK, have already begun investing in Research and Development and have planned to test automotive vehicles as early as spring 2015, as previously mentioned in this document. So far this technology has only been demonstrated in realistic environment experiments as described above. Ireland will need firstly to review its current legislation and seek amendments to introduce such automated technologies to Irish roads. This dissertation will follow the above research areas and topics to understand how ready Ireland is to allow robots take the wheel transporting freight.

2.4.4 Leaders in Autonomous Truck Research

This section will look at the current leaders in Autonomous Truck Technology. There are various companies developing autonomous cars or light vehicles as previously mentioned such as Google, Mercedes, Audi and BMW. However, during the research for this report there was no evidence found of car manufactures planning to develop AV Freight Trucks at present. Research shows the development in freight trucks is more focused on the systems to support the drivers while driving as detailed in section 2.2 of this document.

US Department of Defence have been working to make their military vehicles and trucks driverless since 2005. Tank Automotive Research Development and Engineering Center (TARDEC) believe by 2025 driverless vehicles will be working alongside soldiers and providing aid in dangerous environments (Vergun, David, 2014). June 2014 TARDEC ran a successfully experiment whereby a fleet of military trucks travelled at speeds of 40 mph though varying terrains.
Komatsu is another leading company in mining trucks. As previously discussed the company have been operating AV trucks since 2005, firstly on a trial basis, then 2008 in the West Angelas Mines Australia. By 2014, they have 40 AV trucks in operation.

In 2014, Daimler AG – Mercedes-Benz showcased their Future Truck which they expect to be commercially available by 2025. Daimler will be offer luxury as well as safety within their AV trucks which can currently travel at 55mph. Their aim is to allow the driver to multitask. While the vehicle is in auto drive the passenger can do other things such as bookkeeping, office work, relax and even sleep.

As previously highlighted AB Volvo participated in the SARTRE project which will be reviewed below. This partnership will provide Volvo with greater knowledge and tested information, perhaps offering advantages over their competitors. Volvo plans to have an AV Truck on the road by 2020 (VOLVO GROUP GLOBAL, 2010).

SCANIA is currently participating in the EU funded COMPANION project, which takes up from where the SARTRE project left off. Though no commercial date of release SCANIA have two working AV trucks in operation to explore in greater details how platooning could be implemented.

2.4.5 Research studies to Autonomous Implementation

This section will look at European research projects determining if AV technology could be brought to the highways and roads of Europe.

2.4.5.1 Platooning

The SARTRE project funded by the European Union as part of the Seventh Framework Programme began testing a method of platooning or road trains. The project began in 2009 to assess if it was possible for a convoy of vehicles lead by a lead truck could successful navigate a motorway. The lead truck driven by an experienced driver would be driven manually, while the following vehicles would engage autonomous mode. At this point the vehicles will mirror the actions of the lead truck. The final project report refers to “Driver Comfort” as one of the goals of the project. Passengers will be able to read, use their smart devices, watch a movie or even sleep while they travel.

The research team conjectured this would be a paid service. A payment model would be created to offer users several options to join the convoy. Payment would be collected either as a one off or monthly membership. Lead drivers may even be able to earn additional income due to willingness to guide following vehicles.
The basis of the SARTRE project paper is that platooning is a safer way to travel long distances. It is discussed that platooning reduces carbon emissions and fuel consumption and offers new revenue streams to lead drivers.

When the SARTRE project was completed in 2012 the results proved that it is possible to successfully lead a convoy of vehicles. The technology worked as expected.

A safe and energy-efficient way to travel

2.4.5.2 COMPANION (Cooperative Mobility Solution for supervised platooning)

COMPANION is the project that continues the work of the SARTRE project. It is funded by the EU as part of the Seventh Framework Programme to explore how platooning could be adopted by road users. Having determined that platooning has clear advantages to the driving experience and also benefits the environment. HGV currently account for 17% of total CO2 emissions. Platooning could be seen as an essential step to the European Union’s commitment to reduce greenhouse gases by 20 percent by 2020 (COMPANION Project, 2014).

This three year programme will identify ways to apply the concept of platooning in practice in daily transport operations. The aims of the project are to improve and assess the implementation of platooning. Using the current infrastructure the project will assess a scalable off board decision making system determining the optimal coordination of platoons. Through their experimentation they hope to prove that platooning will increase road safety and provide statistical information on energy reduction.

The project will also explore a standardised support system to be used in European countries. Their findings will help motivate political figures to engage with the automotive industry to encourage a push on AV technology. It would be hoped that all decision makers will support the findings and continue to inform and reassure the general public. When completed, the COMPANION project will
submit a legislative framework to the European Union to suggest amendments to law which prevent the use of AV on the roads of Europe.

SCANIA have taken the lead in supplying AV trucks to take part in the three year project. SCANIA will help to develop a system for implementing truck platooning on roads. “We hope that this project will increase awareness in Europe of the many advantages of platooning,” says Sven-Åke Edström, Senior Vice President, Truck, Cab and Bus Chassis Development. SCANIA will be partnering with Spanish companies IDIADA and Transportes Cerezuela. Through this collaboration they will test the system on Spanish roads during the autumn of 2016 (SCANIA, 2013).

2.5 AV Social and Economic Aspects

This section will give some background to the problems facing the road haulage industry in the US that may encourage the introduction of autonomous trucks. It will then outline discussions relating to the implications of advanced automation systems on workers in the logistics and freight transport industries and also how society may react to the new technology. Some of the papers chosen appear to primarily focus on automation in a manufacturing context but it was felt they were relevant to the subject of automation in the context of freight transport in that they include discussions relating to the social and economic aspects of automation and consider automation from a human-centred perspective. The section will conclude with an outline the possible risks in the event of disruption to road freight as a consequence of over reliance on IT leading to catastrophic system failures.

2.5.1 Acceptance Issues

Rijsenbrij et al. (2006) argue that while automated trucks mixing with normal traffic is technically possible issues relating to public acceptance and legal constraints mean that a dedicated or dedicated/enclosed infrastructure needs to be used. One of the examples they outline is that of Combi-Road, a concept developed in the Netherlands which involved fully autonomous trucks using a dedicated track way as can be seen above in Figure 1. It was designed to transport standard marine containers from the port to an inland distribution centre. A prototype was constructed and tested but the project did not progress past the prototyping stage due to high costs associated with the infrastructure and implementing the technology. Lack of commitment from potential users of the system and political opposition based on a rival rail project were also cited reasons (Van Binsbergen, et al., 2014). In considering the critical success factors of projects like Combi-Road the authors cite several factors such as high developmental or infrastructure costs, intended participants may believe that the implementation of the project may lead to changes in the relationships with clients, changing external conditions such as economic or political factors and overestimation of performance improvements. These factors make potential users reluctant to use the new technologies until they are proven (Van Binsbergen, et al., 2014).
It can be argued that projects like Combi-Road were just ahead of their time and the lessons learned will guide future projects. This literature review describes research projects that are making huge advances in the area of freight vehicle automation which may make projects like Combi-Road more viable in the near future.

2.5.2 Driver Shortage

According to a 2015 report by Business Monitor International 86% of freight tonnage in the US is transported by road. It has been claimed that the over reliance on road haulage is contributing to problems such as congestion, pollution and rising costs (Business Monitor International, 2015). Data from the American Trucking Associations shows there are 3 million professional truck drivers in the United States with the total number of people employed in the sector put at 8.7 million (American Trucking Associations, 2015).

A major problem facing the haulage industry internationally is that of a shortage of drivers. Over the years academic papers have repeatedly reported on the problem. Min & Lambert reported in 2002 that during the previous two decades the trucking industry had shown unusually high annual turnover rates of drivers often as high as 100 to 200 percent. They cite previous research to show the effect of turnover on profitability with the total cost per driver potentially at $15,000 Min and Lambert (2002).

Many strategies were used to try and address the problem such as increasing driver pay, rewards for longevity of service or career advancement. The authors performed a survey of freight companies and made comparisons with previous research. The survey showed that 65.5 percent of the companies reported a driver turnover rate of greater than 10 percent with the main factors the companies believed influenced driver retention being pay and condition of equipment Min and Lambert (2002). The authors found correlations with previous research showing the importance drivers placed in a good working environment and argued that a poor standard of equipment translated into less comfort and safety, more job stress due to equipment breakdown and requiring greater effort to operate.

Jackson et al. conducted interviews with 104 long distance truck drivers. The data obtained from the interviews suggest that the reason for the driver shortage is due to a variety of issues. These can be broken down into different areas. Job related; low pay, government regulations and poor image of the profession. Working conditions; standard of equipment, traffic related stress and excessive time waiting. Quality of life issues such as excessive time away from home and sedentary lifestyle (Johnson, et al., 2010).

Recent reports in trade periodicals suggest that the problem is not improving pointing to the lack of qualified drivers, the improving economy boosting demand and low pay as the chief reasons. The nature of the job does not attract younger people and many smaller operators going out of business during the recession were other reasons quoted (Cola, 2014).

On the other hand one periodical from 2014 argued that the driver shortage was being overstated and government data showed that the number of smaller carriers was increasing as the economy recovered (Berman, 2014). This poses the question whether the core problem is the existing industry capacity as dictated by the prevailing business climate and if so whether autonomous vehicles could solve that problem? This is a question that should definitely be investigated in later research. However on balance it does appear the industry has an ongoing issue with retaining drivers. Reports in trade papers show a similar problem in Europe; The Journal of Commerce reported in 2014 that haulage companies in Europe were facing similar issues; an aging population of drivers, fewer young people interested in the career and tightening government regulations (Cassidy, 2014).
2.5.3 Catastrophic System Failures

Given the continued significance of the road freight haulage industry to the wider economy both in the US and the EU (Marketline Industry Profile, 2015) the number of issues facing it perhaps helps to explain the apparent push towards full automation of freight trucks. However their introduction may face problems such as acceptance from the public and business; one of the advantages claimed for autonomous freight trucks is that they would not be limited by the human drivers need to rest, however one trade publication described the challenges that hauliers operating in the car transporter area faced when trying to get agreement from dealerships allowing them to make deliveries outside normal business hours (Cola, 2014). In addition allowing automated trucks to make deliveries to their business premises could mean that businesses would need to make changes for example to their loading and unloading docks.

Sheridan et al. describe how many trade unions and worker organizations have welcomed automation because of the perceived improvements in the areas of productivity and safety. However, in outlining the impacts of automation argue that while increasing levels of automation work well as productivity is increasing and markets are expanding it may not work when markets stabilize and there is a danger that larger and larger proportions of unskilled or non-technical workers could be left without meaningful work. They further argued that automation can have negative effects on human operators; these include atrophy of skills where the worker may lose the skills to operate the machine or vehicle if called upon to do so in the case of a failure of the autonomous system or encountering a situation that the autonomous system was not able to deal with. Another negative effect may be where the operator has misplaced trust in the autonomous system (SHERIDAN, et al., 1983) which in the case of automotive vehicles may have safety implications.

Martin et al. argue that automation technology systems face particular difficulties in meeting a given set of requirements due to the inherent inter-disciplinary nature of the problems it faces and also because it needs to function in a human environment. There have been notable successes for automation in areas such as manufacturing and air transport. It is argued that this has led it to being seen as a kind of magic bullet to solve complex problems, possibly as a result of careful marketing (Martin, et al., 1990).

In the social aspects of automation the authors argue that machines should always be defined in relation to the subjects of the work i.e. the humans doing the work with the assistance of the machines. The authors note how some automation strategies regard humans as error-prone nuisances to be kept out of the way as much as possible but argue that this strategy may lead to automated systems become dominating factors rather than serving a supporting function. What technology cannot replicate is the decision making abilities of people when faced with unexpected situations or when thing go wrong and someone has to take responsibility. The authors conclude the discussion by arguing that a correct strategy for designers of autonomous systems is one where the person is in charge and outline three design goals; that the systems help correct human error, that they enhance the abilities of the people using them and that they don’t alienate users (Martin, et al.).

As discussed above smart autonomous vehicles will communicate with each other. Possible EU wide ITS infrastructure where the individual components are based on IPv6 technology resulting in the separate systems all being connected to each other. An aspect of interdependent networks is that a failure of one node may result in the failure of nodes which are dependent on it possibly leading to more cascading failures which are out of proportion to the original event (Vespignani, 2010). Buldyrev et al. in a letter to Nature demonstrated how this was possible using as a model the electrical blackout that occurred in Italy in 2003. In a very simplistic description of what occurred a
failure at one power station caused it to become removed from the grid causing internet servers which were dependent on it to also cease functioning. This led to power stations that were dependent on these servers to also stop generating resulting in an electrical blackout that affected much of the country (Buldyrev, et al., 2010).

Longstaff et al. argued that the increased reliance on IT has resulted in adverse impacts that traverse international boundaries. These include; increasing complexity and interconnections between critical infrastructures, the just-in-time model that operates in many industries resulting in less operational buffer and finally increased potential accessibility for hostile actors to critical infrastructures (Longstaff, et al., 2000). Zhang et al. argued that in an interconnected transportation system malware could cause chaos across a wide region. The hostile actors could be criminals, terrorists or even foreign governments (Zhang, et al., 2014).

McKinnon conducted a macro-level assessment of the impact of a failure of a road transport system in the UK. In a hypothetical scenario there would be a total cessation of road freight transport for the period of one week. The scenario was not done specifically from an IT perspective; the two examples which the author gives were related to striking truck drivers in 1979 and fuel crisis which occurred in the UK in September 2000. It was felt however that this scenario is relevant to the present literature review given the previously outlined discussions on the possibility of failures in interconnected networks.

In discussing the previous crises, the drivers’ strike while causing widespread disruption to the distribution of food stocks, occurred in a period before the just-in-time method of inventory management was widely used meaning that the inventory levels were able to provide a greater buffer than they would do able to do so today. The fuel crisis of 2000 resulted in much wider disruption; refineries and fuel depots were blockaded at short notice and within two days half the petrol stations had run out of fuel and supplies to industry disrupted. The protest only lasted five days just as the manufacturing sector was preparing to close down and food supplies in shops were running low.

The author concludes that the loss of road transport for a week would be devastating; while the public may not like trucks they play a critical role in providing the goods and services that maintain their everyday living standards. He argues that not enough research has been done on systemic collapses when entire networks fail and the effects are felt across business sectors and geographic regions. However, he notes that the additional costs of protecting against such occurrences are difficult to justify given that they are so rare.

In the context of autonomous vehicles and advanced ITS infrastructure it is likely to be a some years at least before they would be widespread enough that the kind of failure outlined would cause the disruption described above. This is an area which will require further research. Both the national government and also the EU will need to take these risks into account when defining policy for the adoption of autonomous freight vehicles.

2.5.4 Technology Innovation and the Freight Haulage Industry

The previous 30 years have seen major developments in the design of heavy freight trucks with improvements in the areas of engine power and fuel efficiency, aerodynamics and suspension systems. This has resulted in trucks with greater cargo haulage capacity and better fuel efficiency that require less physical effort from the driver. The last 15 years has seen the gradual introduction of Information Technology systems into trucks with the aim of increasing productivity and fuel efficiency. The OECD 2011 transport report describes these advances as being driven by intense competition between truck manufacturers and environmental and safety concerns. The intense competition between manufacturers drives innovation in the areas of design and manufacture and
marketing (International Transport Forum, 2012). The products resulting from these innovations are then exploited by the logistics and freight transport industry where, in comparison with sectors such as manufacturing the level of innovation was found to be lower (Wagner, 2008).

The possible reasons for this lower level of innovation in the freight transport industry and ways in which it can be better managed was explored in Flint et al. (2005). The authors describe logistic innovation as any logistics related service that is seen as new or helpful to the intended focal audience and could be internal to the company or externally, customer focussed. The innovations could be radical such as the initial change to inter-modal containers or incremental improvements to warehouse management. In the middle are those such as investing in technology so as to provide new or improved services in collaboration with customers. The authors put forward the argument that finding out what customers value and the ability of the organization to learn and share knowledge are key areas to strengthen innovation (Flint, et al., 2005).

Wagner describes how a technological invention alone is insufficient; a company must have or be doing something new that enhances the supply chain such as the previously mentioned inter-modal cargo containers (Wagner, 2008). The development of the inter-modal cargo container that conformed to international standards was a ground breaking innovation in the history of freight transport. It had a wide reaching effect on the wider economy and society as it standardized shipping and reduced transport costs for transporting goods and materials which facilitated the geographic dispersal of manufacturing and production for example to regions where worker costs were not as high (International Transport Forum, 2012).

It is worth noting that the necessary supports for introducing cargo containers appear to have been mostly held within the boundaries of the logistics industry itself and possibly this contributed to its success. Truck manufacturers needed to build vehicles that were capable of transporting the containers but there did not seem to be any need for major improvements to be made to the road infrastructure or physical structure changes to factories etc. specifically to support the use of containers. This may have happened later to accommodate increased volumes of traffic but not at the beginning as is the case with autonomous vehicles. With AV it is likely that major changes will need to be made to roads infrastructures etc. to allow for their introduction.

Fully automated freight trucks operating on public roads are still some years away but there appears to be an underlying theme emerging of the convergence of different technological, economical, societal and political forces. Together they appear to be influencing a trend towards autonomous systems in the area of transport in general leading to fully autonomous vehicles being permitted to operate on public roads at some point in the future. As was mentioned earlier the adoption by road hauliers of on-board ICT systems illustrates this trend towards the gradually increasing use of automation in freight vehicles. ICT is allowing logistics companies to innovate through the incorporation of ICT systems into their fleet that allow them to provide new services to their customers.

Michael Porter has argued that over the last 50 years that Information Technology has twice radically transformed competition and strategy with the first occurring in the 1960’s and 1970’s which involved the automation of individual activities and process standardization in the value chain Porter and Millar (1985). The second transformation occurred in the 1980’s and 1990’s with the advent of the internet leading to the globalization of the supply chain (Porter, 2001). He further argues that a third transformation is about to occur driven by an array of technological innovations that are converging to make smart technologies economical and technically feasible which will enable new functions and capabilities in the areas of monitoring, control and optimization leading up new levels of autonomous operation. These new capabilities will, as did the previous waves of IT driven transformations have the effect of shifting the five forces that drive competition. Which in
turn, will affect the structure in many industries including logistics and road freight transport enabling firms to offer greater customization to clients. His key points are;

- The smart technologies will reduce or mitigate buyers bargaining power by moving competition away from price alone and allowing firms to reduce dependency or disintermediate service partners.
- With particular significance for the freight transport industry the technology will enable firms to offer greater customization to clients, shifting rivalry with their competitors. However there could be a danger of a feature and a function arms race with competitors that would escalate costs.
- Even with the technical advances it seems likely that there would still be higher fixed costs associated with investing in the new systems although these would probably decrease over time as the enabling infrastructures are put in place allowing the technology to become more widely adopted and to mature.
- The higher fixed costs of investing in the new technology could also raise barriers to new entrants in the sector but could also have the effect of lowering barriers by allowing new entrants to challenge existing players.

Porter and Heppelmann (2014)

This last point can be seen today in the automotive industry where technology companies like Google and Apple are starting to challenge major players in the automotive industry by using their existing specialist knowledge and culture of innovation to begin expand into areas they were not traditionally associated with. The end-result of this research could be transport related IT systems provided as a service. This could enable new business models in freight transport allowing new entrants to offer highly customizable services to clients.

As the technology becomes available Porter and Heppelmann highlight several key risks for firms. The first of these is ensuring there is value in adopting the new technology and services. Given the gradual introduction of new technology over the last several decades it can be assumed that management in the road freight transport industy will be experienced enough to form a judgement on the new solutions when they arrive. Other keys risks identified were underestimating the security and privacy implications and failing to anticipate new competitive threats that emerge as a result of changes to the industry structure brought about by the new technology (Porter & Heppelmann, 2014).

The concerns about security and privacy are echoed by Shin (2014) who while analyzing the emergence of the Internet of Things (IoT) in Korea describes the security and privacy implications of smart connected technologies as a "huge concern". Many of the observations and questions that the author raises appear also to be relevant when considering the development of automated vehicles. In discussing applications of the IoT the author posits the emergence of an Internet of Vehicles (IoV) making transport easier and safer and how the IoT will allow ICT to penetrate further into manufacturing and distribution. The author observes that in this early stage of development the primary focus has been on the technical side with less attention being given to social issues (Shin, 2014, p. 527). The author argues that although the technology is evolving too quickly for governments to make many policy recommendations; areas such as promoting research and facilitating the setting of standards are ways in which they can exert some influence (Shin, 2014, p. 528).

2.6 AV Policy and Legal Aspects

This section first describes the policy approach the EU has been and is taking to manage the introduction on ITS into the transport systems outlining the Action Plan and Directive and briefly
discusses the progress that has been made to date. It goes on to describe what appears to be the most current policy making initiative in the area of intelligent transport in the EU; Co-operative ITS (C-ITS). The section will then review the work being carried out in the US and in Europe to update the legislative and regulatory framework to facilitate research into advanced vehicle technologies and discuss what steps Ireland will need to take if the government decides to address the issue.

2.6.1 Government policy

In 2008 the EU commission adopted an Action Plan for the deployment of ITS for road transport which identified priority areas. This was followed in 2010 by Directive 2010/40/EU which provided the legal structure. The aim of the Action Plan and Directive are to establish a framework to coordinate the deployment and ensure the compatibility and interoperability of ITS solutions across the EU member states (EU Commission, 2014). The Action Plan identified priority areas such as promotion of vehicle safety systems and the integration of the vehicle and transport infrastructure. The Directive defined the necessary requirements for the provision of travel and traffic information services for private and commercial vehicles across the EU.

A review of the action plan was undertaken in 2013. It was found that overall the implementation of the plan was well advanced but most ongoing actions were experiencing delays due to the complexity of some of the areas. Action Area 4; Integration of the vehicle into the infrastructure was one of the areas reprioritized. The definition of a medium to long term deployment and investment roadmap for intelligent infrastructure to support co-operative vehicle systems was given a high priority.

Possibly in response to the reprioritization of co-operative vehicle systems together with the rapid advancement in smart vehicle technology and ongoing high-profile autonomous vehicle research projects in 2014 DG MOVE set up the Co-operative platform (C-ITS) to address the policy requirements for connected vehicles. The platform is made up of C-ITS experts from public and private organization from across the EU member states. It will address areas where there are unresolved issues in an EU wide deployment of co-operative systems such as; legal, organizational, governance, technical, standardization and public acceptance. The areas have been broken up into a set of work packages;

1. Cost Benefit Analysis
2. Business Cases and Business Models
3. Open Legal Issues
4. Governance of the System & Privacy
5. Security and Certification
6. Technical Issues
7. Standardization Issues
8. Public Acceptance
9. Implementation Issues
10. International Cooperation
11. Roadmap for Deployment

This draft work program appears to be very comprehensive and addresses many of the issues surrounding autonomous vehicles. However it is still only a discussion document. Point 11 states that the aim is to produce policy recommendations and proposals for actions towards the actual adoption of an official roadmap for the deployment of C-ITS. This will need the agreement of a wide spectrum of stakeholders from within the EU and also co-ordination with corresponding connected vehicle policy bodies in the US and Japan.(European Commission, 2014)
The policy recommendations may eventually become incorporated into directives which EU member governments may or may not sign-up to or else some may become EU regulations.

A regulation is a legal term for a rule made by and maintained by government authorities and enforced by law. Under the European Union regulations are legal acts that are immediately enforceable in all member states simultaneously. Regulations are different to directives as regulations need to be transferred into national law.

Moon et al. (2014) carried out a comparative analysis of the laws on autonomous vehicles in the U.S. and Europe. In conclusion (Moon et al., 2014) discovered there is little advancement pertaining to implementing laws for autonomous vehicles pass a certain level of automation. To further explain this, the authors categorised automation into four levels of automation in order to understand the level of automation and associated laws.

**Level 1:** automation groups the earliest of automation capabilities such as cruise control and anti-lock braking systems.

**Level 2:** refers to the autonomous technologies that assist the driver’s perception but does not relinquish the driver. Examples of Level 2 automation include reverse collision warnings, blind spot monitoring and lane departure warnings. Level 2 automation technologies add to the safety of a vehicle however can still be override by the human. Both level 1 and 2 technologies are present in most vehicles today.

**Level 3:** This level of automation is not currently available on the market however manufacturers are currently testing these levels of automation with prediction of reaching the market by 2020. Level 3 automation includes lane-keeping capability where a feedback control via level 1 cruise control technologies can input to the vehicles steering. Vehicle to vehicle (V2V) communication and vehicle to infrastructure (V2I) communications that allow for cooperative cruise control and platooning are grouped as level 3 automation.

**Level 4:** Refers to fully autonomous vehicles. Automatic parking technologies are considered as level 4 automation as all control is given to the technology.

The authors found that there is little guidance beyond level 2 automation. Currently leading the way to implement changes in legislation to allow autonomous vehicles are the U.S. states of California and Nevada (Moon et al., 2014).

### 2.6.2 Legal Implications

It is evident from the advances being made into autonomous vehicle technologies that the readiness of the technology will not be the barrier to this innovative technology. What would appear to be the barrier are the legal and regulatory frameworks in place in order to allow the testing and operation of autonomous vehicles.

As countries move forward in the race to develop and test autonomous vehicles nationally an examination of the current legal and regulatory frameworks within Europe and Ireland will be explored. An observation of the advancements of other countries worldwide will be carried out to answer the research question of what will Ireland need to do to allow freight autonomous vehicles on Irish roads.

In the course of conducting this literature review no evidence was found to show that Ireland is preparing for such a review of its current legal framework in anticipation for this innovative and fast evolving technology. The policy document outlining transport strategy for Ireland for the years 2009-
2020 the Irish government stated that in most cases Ireland is a technology taker relying on vehicle manufacturing countries to deliver technological improvements. It goes on to say that the most effective approach for Ireland is through engagement in shaping EU policy. However the report does state that “individual actions at national level demonstrate commitment to the type of change required (Department of Transport, 2009). This statement seems to refer to the implementation of some of the points contained in the EC Action Plan and the EC ITS Directive. However the actual implementation appears to be selective depending on the costs involved in upgrading infrastructure. This is based on the decision by Ireland along with six other countries not to sign up to the EC ITS Directive part D which was for an interoperable EU-wide eCall; an automatic call made by the vehicle in the event of an accident (European Commission DG MOVE, 2010, p. 20). The statement could also indicate the possibility that the Irish government might consider investing in innovative ITS projects if they were demonstrated to have value.

The UK have already began with governments investing in Research and Development and amendments made to legislation to allow the testing of automotive vehicles since January 2015. The Department of Road Transport in the UK department is responsible for the research and development of autonomous projects. The Department of Road Transport considers the UK as having one of the most welcoming regulatory environments for development of this technology than anywhere in the world (UK Department of Transport, n.d.)

In order for Ireland to follow suit with the UK to begin to test autonomous vehicles, a review of the current legislative and regulatory framework will need to be conducted. Ireland needs to examine if its legal framework is acting as a barrier to this technology. If so, amendments will need to be sought to its legislation in order to introduce automated technologies to Irish roads.

To understand the legal implications Ireland will face it will be important to understand the Irish legal system. The Irish law system is a common law system. Acts are made by the Oireachtas and any subsequent amendments or reviews to Acts must follow an amendments process. Acts of the Oireachtas are referred to as primary legislation. The Road Traffic Act is a primary legislation of the statute law. Secondary law refers to statutory Instruments; orders, regulations, rules, bye-laws and schemes. Statutory Instruments do not need to be passed by the Oireachtas and can be introduced by bodies with legislative power. Statutory instruments are used in cases to pass through EU directives.

As Ireland is a member of the European Union, Ireland is bound to European legislations. The two acts that will need to be amended to allow the testing and future developments of automated vehicles are the Road Traffic Act and Road Transport Acts.

There are a number of areas where changes will need to be made to cover the following;

1. Vehicle Registration, Ownership and Licencing
2. Vehicle Roadworthiness and Vehicle testing
3. Driver Behaviour and the Law
4. Insurance requirements – Vehicles or Humans

Under the road traffic act, sections relating to driver offences such as dangerous driving, careless driving, driving under the influence of an intoxicant and mobile usage will need to be reviewed in current laws.

Additional laws going forward could be the upkeep and maintenance of automated vehicles and liability issues will need to be explored regarding the testing of software and performance of the autonomous vehicles.
2.6.2.1 Autonomous Vehicle laws in the U.S.

Moon et al. (2014), mention that necessary legal framework required to create a framework for the testing and operation of level 3 autonomous technologies on public roads ranges from non-existent to “under development.” In order for the U.S. to implement a legal and regulatory framework for the testing and operation of autonomous vehicles it will require to make changes to both the federal regulations and state regulations. Thus far reports of changes to the federal regulations are focusing on the standardisation of the technology aspects of the automation and not the operational use. State regulation is leading the way within the US with four states and the District of Columbia passing bills for the testing and operations of autonomous vehicles.

2.6.2.2 Autonomous Vehicle laws in Europe

Within the EU the amendment to the United Nations Convention on Road Traffic agreed last month will allow motorists to take their hands off the steering wheels of autonomous vehicles, provided there's a way for drivers to switch off the self-driving systems if necessary. The amendment had marked a significant advancement for the EU and its legal frameworks towards its preparations of autonomous vehicles.

All EU countries with the exception of the UK and Spain had signed and ratified the Convention of Road Traffic (1968) which stated that any moving vehicle must be controlled at all times by a person driver.

The below sections of the Vienna convention required amending before autonomous vehicles could be possible. European countries France, Germany and Italy lobbied for the updated provision – The amendment was submitted by the governments of Germany, Italy, France, Germany, Belgium and Austria, according to the April 17 U.N. document.

Article 8 Sections 1 and 5 of the Vienna Convention requires that “[e]very moving vehicle or combination of vehicles shall have a [person] driver,” and “[e]very driver shall at all times be able to control his vehicle.” (Europe, 1968)

Article 13 Section 1 of the Vienna Convention further requires that “[e]very driver of a vehicle shall in all circumstances have his vehicle under control so as to be able to exercise due and proper care and to be at all times in a position to perform all manoeuvres [sic] required of him.” (Europe, 1968)

The amendment agreed would allow a car to drive it, as long as the system “can be overridden or switched off by the driver”. A driver must be present and able to take the wheel at any time. Countries would then be required to adopt the new policy into national law. Provided the amendment clears all bureaucratic hurdles, all 172 countries that are party to the convention would have to work the new rules into their laws.

However, testing on private roads under ad-hoc legal permits has happened on local and regional level. Table 1 outlines an example of these projects (Moon, et al., 2014).

Table 1 below provides examples of such test projects of AVs on public roads.
Is Ireland ready to let robots take the wheel transporting freight? – **Team 8**

<table>
<thead>
<tr>
<th>Name of Project</th>
<th>Place</th>
<th>Announced Time Frame</th>
<th>Level of Autonomy</th>
<th>AV Tested</th>
<th>Legal Permit</th>
</tr>
</thead>
<tbody>
<tr>
<td>MadeInGermany (Autonomos Labs Website)</td>
<td>Berlin and Brandenburg States</td>
<td>2011-7</td>
<td>Level 3</td>
<td>Outfitted Volkswagen Passat</td>
<td>Testing license/exceptional permission from local Berlin authorities (LABO Berlin)</td>
</tr>
<tr>
<td>Citymobil2 (Citymobil2 Newsletter No. 2, 2013)</td>
<td>5 EU cities TBD</td>
<td>2014-2016</td>
<td>Level 4</td>
<td>INDUCT Navia vehicles; Robosoft VolcanBul vehicles</td>
<td>TBD based on cities chosen for the pilot program</td>
</tr>
<tr>
<td>Drive Me (Volvo Press Release, 2013)</td>
<td>Gothenburg, Sweden</td>
<td>2017-</td>
<td>Level 3</td>
<td>100 Volvo XC90 vehicles</td>
<td>Unknown; the Swedish government is a party to the project</td>
</tr>
</tbody>
</table>

**Table 1: Examples of test projects of AVs on public roads**
(Moon, et al., 2014)

### 2.7 Summary

The literature review looked at the subject of autonomous freight vehicle and the implications for their future introduction onto public road under the themes of technology, applications, socio economical and finally the policy and legal aspects.
Is Ireland ready to let robots take the wheel transporting freight? – Team 8

Technology
The literature demonstrates how AV technology has been developing over the past two decades. The research available observes a vast array of AV technologies in different areas of the automotive industry. The literature agrees AV technologies use a combination of systems such as sensors (radar, laser and others), video cameras, parking assistance systems to name but a few. The literature consistently shows that the existing automation is focused on supporting the driver while they are driving with several companies working on technology for fully autonomous vehicles without the requirement for a driver.

Applications
From the literature reviewed it was observed that, currently, the application of existing AV technologies does not replace the driver and so existing vehicles are not fully autonomous. The road freight industry has slowly embraced some of the advancement of AV technology and some autonomous technologies can be found in different manufacturers’ trucks, for example Volvo’s high end models. Currently the technologies found in trucks assist the driver in different automated functionalities but the driver reserves the option to perform those actions manually. Literature shows different areas in which such technology has been applied as well as different experiments and trials that have taken place. It also describes possible uses on public roads of the technology such as platooning.

Social and Economic Aspects
The literature is in agreement regarding the challenges the technology will face. It highlights that the technology will have to overcome barriers such as public acceptance and legislation restrictions before it can be implemented on public roads, Rijsenbrij et al. (2006). The papers consistently reported issues of drivers’ shortage in the freight industry, at an international level. Min and Lambert (2002) reported in 2002 that during the previous two decades the trucking industry had shown unusually high annual turnover rates of drivers often as high as 100 to 200 percent. The literature demonstrates there is no solution to solve the problem and so it can be observed that AV could be a viable solution to resolve the problem.

Literature is in agreement of the important aspects that must be taken into account when humans rely so heavily in IT. It is discussed how dependent humans would become with automation and the very negative implications that this could have. Zhang et al. argued that in an interconnected transportation system malware could cause chaos across a wide region. The hostile actors could be criminals, terrorists or even foreign governments (Zhang, et al., 2014)

At the same time available literature analyses the new and emerging technologies and the capabilities they provide. Authors agree on the benefits automation can bring to industries including logistics and road freight transport as they will be able to provide greater customization to customers. Shin posits the emergence of an Internet of Vehicles (IoV) making transport easier and safer and argues that advances in smart technology will allow ICT to penetrate further into the manufacturing and distribution process. (Shin, 2014)

Policy and Legal Aspects
The publications available demonstrate how governments and government bodies such as the USA and EU Commission are changing legislations to provide the legal infrastructure to implement Intelligent Transport Systems on public roads. At the same time evidence shows that not all countries are changing their legal framework to embrace the technology. Regarding Ireland, the literature found demonstrates the country has not taken any steps in anticipation for AV technology. Former Irish minister of transport Leo Varadkar said “It is absolutely the case that technology is ahead of legislation, but it is very hard to write legislation in anticipation of technologies that might or might not develop” (Irish Times, 2014)
Chapter 3: Research Methodology

For the purpose of this study the research team identified the need for a project management tool to visualise how the dissertation was tracked. The tool chosen for the planning and monitoring of the work was Gantt chart because of the researchers’ familiarity with the tool. Appendix 1: Dissertation Schedule shows the graphical illustration of the scheduling, coordination and tasks tracking displayed against time of the work carried out during the dissertation process.

3.1 Introduction

This chapter will describe the methodology used to structure the dissertation. Having decided on a multimethodology approach the dissertation will draw upon Mingers multimethodology framework to create stages to ascertain the viability of autonomous freight vehicles on the roads of Ireland. It will be used to answer the question “Is Ireland ready to let robots take the wheel transporting freight?”

3.1.1 Rationale

When deciding on a methodology for this dissertation the investigators reflected on the topic. The question being asked touches many aspects of society, labour, technology, government policies and law. It is the aim to have an inclusive viewpoint without isolating world spheres as described in Habermas’s Three Worlds [3.2.1] and still keep focus on the paper’s question.

It was considered, using qualitative methodology induction research to form a narrative to explain the topic, perform semi-structured interviews, analysis of the literature review and suggest policy improvements. However, this appeared hollow and did not seem to provide a complete overall picture of what the investigators wished to achieve. It does offer a level of freedom to creatively interpret the data.

It was also considered, to use a quantitative methodology through deductive methods. Breaking down the topic into factual data provides interesting results, but appears cold especially analysing social implications. It does, however, support objectivity of the investigator by its structured rules.

Each methodology brings with it merits and flaws to this research paper, conversely, together they would create a fuller picture of the implications of freight AV in Ireland. To do this, multimethodology was chosen.

Multimethodology offers the best of both traditional methodologies, the freedom to interpret data creatively and also to bend structured rules to explore alternative results and method. Unfortunately, this is why methodology traditionalists refrain from mixing methods as it is seen as open to interpretation and having a weak structure. It is the belief of the investigators that a respectful approach to multimethodologies can provide interesting results as long as they are backed up with data. Brannen (2003) states “mixed methods research is an opportunity that deflects attention away from theoretical work that is often specific to particular disciplines. Thus it may encourage thinking ‘outside the box’, a practice to be welcomed.”

From the investigators appreciation of multimethodologies it occurred to them that its approach related to social research methodology. There is growing adopting in science and business management. This interest in multimethodologies could relate to diversifying roles in the workplace. This paper is based on Information Systems within the School of Computer Science and Statistics which would have satisfied either quantitative or qualitative approaches. Because of the social elements of the paper it was determined that multimethodologies would also explore this area.
Freight AV will have a massive effect on the public and their perceptions of it. The investigators did not have the manpower or resources to conduct public surveys on freight AV. Favouring, semi-structured interviews with experts in the Irish freight industry. Using a literature review method, semi-structured questions were constructed for the freight industry experts. The investigators questions were high level and accepted personal opinions towards freight AV.

Hodgkin’s (2008) researched Women’s Social Capital using mixed methods. She began with a quantitative component and ended with a qualitative component. Doing so helped explain complexities in the quantitative data. The goal was to identify any gender differences between men and women’s social capital profiles. According to Tashakkori and Teddlie (2010), the study does not take into account the types of women in the study (for example, women of a certain class or race). Hodgkin may bring other methodologies into her design in future iterations to address these gaps.

3.1.2 What is a methodology?

Mingers states “a methodology is a structured set of guidelines or activities to assist people in undertaking research or intervention”. These guidelines or activities can be used to create a constructive generic research framework. Methodologies can be used to support the researcher when embarking on a research project and identifies the methods to be used there in. However, a methodology does not define specific methods, which is contrary to the time spent on the nature and processes to be followed to attain an objective or procedure. Mingers goes on to state “Commonly, a methodology develops within a paradigm either explicitly or implicitly and represents the philosophical assumptions and principles of the paradigm. Paradigm can contain more than one methodology.”

It is considered, that a methodology will develop within a paradigm and will represent the philosophical assumptions and principles of the paradigm. A methodology postulates the type of undertakings and techniques that are to be actioned. The methods are the ways to perform these activities and a paradigm stipulates the reasoning for the methodology. It can be considered the relationship between methodology and methods as “what” and “how”.

3.2 Multimethodology (MM) Framework

Multimethodology draws upon more than one paradigm to achieve a greater understanding of the research. Minger advocates the use of multimethodology as moving away from paradigmatic isolation. Minger argues there are four benefits to using multimethodology. Firstly real-world problem situations can be complex and multi-dimensional. Only limiting research to a singular paradigm may not fully realise the scope of the research. Multimethodology allows the encompassing of more than one paradigm it can provide a richer interpretation of the real world. Secondly, some approaches of methodologies are more complete than others, being able to mix approaches offers stronger results. Thirdly, there is a growing appreciation of multimethodology as more people see the benefits of combing methodologies in practice. Finally, arguments from a postmodern perspective also support pluralism in methodology.

Minger adapts and draws on Habermas’s Three Worlds and Checkland & Wilson’s Soft System Methodology to create a framework to decide which multimethodology is suitable to conduct research.

3.2.1 Habermas’s Three Worlds

Habermas suggests dividing the world into three parts to assist analysis— the material world, the personal world and the social world. The purpose is to segment human activity; in reality it would involve all three. Minger explains that a simple conversation has physical dimensions such as body posture/ gesture and spacing; personal dimensions such as emotions and beliefs; and social
dimensions such as linguistic and social practices and power relations. Each domain has different modes of existence and different means of accessibility.

3.2.2 Material World

Mingers describes the material world as being shaped through our actions but also subject to its constraints. It is one of observations that are theory and subject dependent. This world’s viewpoint is of objectivities independent of the observer. It is the world of evolution and development which leads to the social and personal worlds.

3.2.3 Social World

The social world is a human construct that individuals share. It is complex multi-layering of language, meaning, social practices, rules and resources that both enables and constrains individual actions. This world’s viewpoint is of intersubjectivity as it does not concern itself with the individual but the collective.

3.2.4 Personal World

Individuals do not observe the personal world, but experience it through their thoughts, emotions, experiences and beliefs. It is subjective to the individual’s viewpoint. Mingers (1997) describes the personal world as consisting of the totality of subjective states of an individual to which that individual has privileged access but only insofar as these could be, or are, actually presented to others.

3.2.5 Soft System Methodology (SSM)

Checkland and Wilson developed a methodology to systematically tackle real world situations. It can be used to reflect human understanding and develop systems to solve problems. Mingers uses elements of SSM to create stages of the multimethodologies process; they are appreciation, analysis, assessment and action (Mingers & Brookesby, 1997).

Appreciation of the problem as experienced by the researchers, they will fully explore the research topic. Initially they will be required to interpret the problem or situation from their own personal perspective and prejudices. Analysis of the research question or situation will begin by applying different world viewpoints applicable to the methodology. Assessment of how the situation could be realised or changed. Examine the constraints and determining if they can be altered. Action desirable changes to the situation, or offer alternatives and recommendations.

3.2.6 Mingers Framework for Mapping Methodologies

Mingers applies Habermas Three Worlds and Checkland and Wilson’s Soft System Methodology to the framework as how they may be arranged to map a methodology. This can be seen in Table 2. The reason for doing this is to provide a greater understanding of the complexities of the real-world.

<table>
<thead>
<tr>
<th>Appreciation of</th>
<th>Analysis of</th>
<th>Assessment of</th>
<th>Action to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>social practices, power relations</td>
<td>distortions, conflicts, interest</td>
<td>ways of altering existing structures</td>
</tr>
<tr>
<td>Personal</td>
<td>Soft System Methodology</td>
<td>differing perceptions and personal rationality</td>
<td>alternative conceptualisations and constructions</td>
</tr>
</tbody>
</table>
Is Ireland ready to let robots take the wheel transporting freight? – **Team 8**

<table>
<thead>
<tr>
<th>Material</th>
<th>Statistics &amp; Soft System Methodology</th>
<th>underlying causal structure</th>
<th>alternative physical and structural arrangements</th>
<th>select and implement best alternatives</th>
</tr>
</thead>
</table>

**Table 2: Mingers Framework for Mapping Methodologies**

In Table 3, Minger provides an example of how a multimethodology would look like. The methodologies are split or partitioned into components and these are combined together to construct an ad hoc multimethodology suitable for a particular problematic situation. The parts may come from methodologies in different paradigms.

<table>
<thead>
<tr>
<th>Social</th>
<th>Critical System Heuristics &amp; Soft System Methodology</th>
<th>Analysis of</th>
<th>Assessment of</th>
<th>Action to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal</td>
<td>Soft System Methodology</td>
<td>Soft System Methodology + Cognitive Mapping</td>
<td>Soft System Methodology</td>
<td>Strategic Choice</td>
</tr>
<tr>
<td>Material</td>
<td>Statistics &amp; Soft System Methodology</td>
<td>Viable Systems Method</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3: Mingers possible Multimethodology Design**

In Table 4, Mingers framework is applied to this dissertation showing the various stages that must be taken to reach a conclusion. It will provide a plan on how to approach each stage of research. It currently does not include other methodologies, it does however allow for their introduction for future iterations of this dissertation. As the researchers acquire greater understanding of other methodologies they will be able to apply them to the framework.

<table>
<thead>
<tr>
<th>Social</th>
<th>Effect on Society</th>
<th>Analysis of</th>
<th>Assessment of</th>
<th>Action to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal</td>
<td>Interviews</td>
<td>Projects, Observations, Current Literature, Legal, Proficiency</td>
<td>Experiments, Testing, Mix Methods Research(MMR), Constraints Praxis</td>
<td>Offer Recommendations, Future Testing, Recommend changes to policy Publish/Politics</td>
</tr>
<tr>
<td>Material</td>
<td>The Topic Question, Chosen Paradigm, Pragmatism</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 4: Interpretation of Mingers Framework to Map Multimethodologies**

3.3 **Aligning Mingers Framework with Cameron’s(2011) 5 P’s Research**

Having created a multimethodology framework to structure the dissertation it will now be aligned with Cameron’s 5 P’s research as seen in Table 4. Cameron adapted Brannen’s (2005) 3 P’s of research, Paradigm, Pragmatism and Politics framework by adding Proficiency and Praxis to the mix. In doing so defines the actions of the dissertation and evaluates the skills of the researchers. To
provide greater clarity another row was added to Table 4, Intervention, research, methods and conclusion/testing. This maps out the flow of the dissertation and guides the research through each stage.

3.3.1 Method

Methods define the actions to be taken for data collection or how a specific result is to be calculated. How the method will function is described within the methodology. The decided method will develop a research process to quantify the qualitative information captured through semi-structured interviews.

3.3.2 Constraints

The investigators’ inexperience in the field of multimethodology research will be a constraining factor. There are limited resources to conduct a larger scale sample of the freight industry. In response a small sample size of freight industry policy makers were contacted as part of the research process. The investigators do not have access to experimental models to test the feasibility of freight AV. Instead the research relied on the findings of other researchers and motor vehicle manufacturers to assist in the research. Ireland does not have an automobile manufacturing industry, so it can be augured that without lobbying or pressure from such an industry it would be difficult to gain traction unlike other nations that produce vehicles. Research has been constrained to only freight industry policy makers based within Ireland. It was decided not to interview freight drivers as it can be assumed such interactions would be negative.

3.3.3 Three approaches to research

This section will discuss three approaches to research, quantitative, qualitative, or mixed. It will shape how the dissertation will conduct research to best fit the subject matter. The desired approach will contain the knowledge claims, methods and strategies to be used.

3.3.4 Qualitative

Creswell (2003) explains “a qualitative approach is one in which the investigator primarily uses postpositive claims for developing knowledge employs strategies for inquiry such as experiments and surveys and collects data on predetermined instruments that yield statistical data”. It is a strict approach whereby the investigator must follow an agreed structure with little or no deviation.

3.3.5 Quantitative

Creswell (2003) describes this approach “in which the inquirer often makes knowledge claims based primarily on constructivist perspectives (i.e. the multiple meanings of individual experiences, meanings socially and historically constructed with an intent of developing a theory or pattern) or advocacy/participatory perspectives (i.e. political, issue-oriented, collaborative or change oriented) or both”. In this approach the research collects open-ended data with the intent of developing themes from the data. It offers the research more freedom to be creative and innovative with the date produced.

3.3.6 Mixed Methods Research (MMR)

Creswell (2003) describes “a mixed methods approach is one in which the researcher tends to base knowledge claims on pragmatic grounds (e.g., consequence-oriented, problem-centered and pluralistic).” The investigator is able to collect data either simultaneously or sequentially to best understand the research problem. In the process of researching, the investigator collects both numeric (e.g., by testing) and text information (e.g., on interviews) so that both quantitative and qualitative information is recorded and interpreted. This approach offers the greatest adaptability
and flexibility to research. It requires the investigator to be well versed in both qualitative and quantitative methods.

3.4 5 Ps Research

This 5 Ps research work well by aligning to Mingers multimethodology framework to form the instructions on how to proceed with each phase of research. Each phase will progress to a greater understanding of the current perception of AV within the freight industry, future developments and the readiness of Ireland to adopt this new technology.

3.4.1 Paradigms

Neuman (2006) refers to paradigm as ‘A general organizing framework for theory and research that includes basic assumptions, key issues, models of quality research and methods for seeking answers’. Whereas, Denzin and Lincoln (2009) describe a paradigm as, “The net that contains the researcher’s epistemological, ontological and methodological premises may be termed a paradigm. As all research is open to interpretation it will inevitably be driven by the researchers own beliefs and feelings of how the world is understood and studied. A paradigm is a distinct set of philosophical assumptions, concepts, research methods, standards and theories that define the nature of possible research and intervention. It can be used to provide model problems and solutions. A paradigm requires a closed system which can accept changes.

The dissertation will be structured using a single paradigm stance Teddlie and Tashakkori, (2010). Initially formulated to provide the philosophical foundation for MMR- sometimes referred to as the “alternate paradigm stance’ (Greene, 2007). A single paradigm stance requires a mix of methods to properly interpret the philosophical underpinning of MMR. It will allow the dissertation to align the chosen research approach paradigmatically. With a greater understanding of different methodologies the dissertation will grow, drawing greater pools of research as new systems are added. This is especially true as research is ongoing in other European countries. Providing a framework from an Irish perspective will be important when Ireland is ready to adopt freight AV.

3.4.2 Pragmatism

Cameron (2011) believes that pragmatism is the bridge between philosophy and methodology. It was decided to use a praxiology philosophy to guide this dissertation to critically analyse the preparedness of Ireland to adopt AV within the freight industry. The challenges that the researchers face will be resistance from freight companies in Ireland who may be ill equipped, unknowledgeable or resistant to change.

It can be assumed freight drivers would be resistant to change and may feel AV would be a conflict of interest. It was decided not to contact the Department of Transport for comment. It can be assumed that their response will only reflect public record knowledge and personal opinion would be repressed. The dissertation mentioned earlier political sentiment from an Irish Minister in section 2.1.1. The public was also not interviewed as it would stray away from the dissertations topic.

The parameters of the semi-structured interviews were conducted with five freight policy makers with vested interest in the freight industry. They were interviewed to discuss the possible inclusion of AV technology within their organisations.

3.4.3 Praxis

Praxis is the practical application of theory within mixed methods research. The researcher is required to be knowledgeable, informed and familiar with multimethodology. The researchers understanding is key to relate praxis with methodological and data integration of mixed methods research (MMR). Morse’s (2010) 5 Mixed Methods Research was used to structure the papers
research design. The research methods deployed: Theoretical Drive, Core Component, Supplemental Component, Pacing and Point of Interface.

**Theoretical Drive**
Theoretical drive is the overall inductive, deductive or abduction direction of a research project (Morse, 2003). It guides the use of the appropriate qualitative and/or quantitative methodological core. The literature review did not uncover previous research on the Irish freight industry adopting AV. It can be assumed that the direction of the project will be inductive. However, as this is the first iteration of this research in Ireland it will benefit from deductive reasoning as well to enforce future research testing. As such, abduction (both inductive and deductive) will be used to guide the research project. Abduction will allow the research team to quantify the qualitative data and provide a baseline for future research and iterations of this paper. The direction of this strategy will enhance the qualitative description to understanding or provide an explanation by collecting and analysing quantitative data separately.

**Core Component (Qualitative)**
Research will be conducted using a qualitative core component for the project (abduction theoretical drive) with a sequential quantitative supplementary component. There is a lack of secondary information regarding research in the Irish freight industry to adopt AV. Primary research will be gathered by semi-structured interviews. A selection of Irish freight industry policy makers were interviewed using semi-structured questioning. The meetings were recorded and transcribed for dissemination. This information will be invaluable to answer the topic question. It was determined that blind surveys, though having a larger response rate, may not provide accurate or meaningful replies. It was decided a low number of policy makers would be far more meaningful than a large number of random cross sections of the public.

The semi-structured interviews will provide an understanding of today’s perceptions of the Irish freight industry to adopt AV and Irish road infrastructure preparedness. This qualitative data outcomes can standalone and offer insight into the current status of AV development if any in Ireland. It is hoped that the supplemental quantitative data will initiate actions to narrow the gap between Ireland and other nations’ further advancement in this area. A qualitative report on the semi-structured interviews’ transcript will be undertaken to postulate a narrative that answers the papers question “Is Ireland ready to let robots take the wheel transporting freight?”

**Supplemental Component (Quantitative)**
The core component has drawn conclusions based on the semi-structured interviews and it is assumed to have answered the topic question. To expand on the useful data collected a quantitative supplemental component will be added. This method of turning qualitative data to quantitative data will provide a baseline for future research in this area. Due to the small sample size it was deemed unnecessary to use a chi-square to interpret the data, instead a spreadsheet was used. How it was implemented will be shown in the analysis in Chapter 4.

A baseline displays data over several years. It develops in two parts. Firstly, showing historical information where we have been and secondly forecasting to show where we are going if we stay on the current course. Baselines define current position and how it develops over time.

The paper was unable to source data on AV adoption in the Irish freight industry. Instead the paper used assumptions to develop its own baseline. It draws on current information through the literature review method and semi-structured interviews.
Compiling results over time will add to the narrative of the paper. Of course, it will be expected that assumptions will be replaced with factual information which will impact on the baseline score. As such the baseline model will record any anomalies or changes to it as it nears its five year duration.

**Pacing (Sequential)**

Sequential research is conducted in a stage approach where one stage will be completed and followed by another over and over again. The purpose is to build on the sample information of the previous stage. After each sample is analysed the researcher can accept the hypothesis or select another pool of subjects before a final decision is made to accept the findings. At this point the research can choose to use an alternative technique to gather data and applying different methods to them. The limitation of this paper mean only five interviewees were used. However, it could follow the supplementary component as a baseline for future research.

It was decided sequential pacing was to be used to interpret the semi-structured interview findings. Developing a quantifiable framework for further research in this area required interviews to take place first. After the interviews were transcribed they were interpreted and scored to be form a quantifiable data set.

**Point of Interface**

Empirical analysis is a way of gathering and creating knowledge by means of direct and indirect observation or experience. This paper uses an empirical question which it is assumed will be answered by the conclusion. Using empirical analysis to develop a model of concept to reinforce the qualitative outcomes will provide a better understanding of the topic question.

**3.4.4 Proficiency**

The research data represented within this dissertation was collected in a non-prejudicial way. The collection process and implementation by the research team do not have a vested interest in the Irish freight industry. This approach provided an objectivity to perform interviews without bias and scrutinise the advantages and disadvantages of AV. Using mix method research to integrate quantitative and qualitative data achieved a clear and informed answer to the question is “Is Ireland ready to let robots take the wheel transporting freight?”

This is the first time the researchers approached mixed methods research. Though inexperienced they are competent in data collection and forming said data into an understandable and informative arrangement. It could be argued that a lack of theoretical practice and a business understanding provided a fresh look on mixed methods approach.

**3.4.5 Politic**

Brannen (2005) surmises, “the political researcher is concerned about forms of knowledge and ways of knowing – research for whom and for what?” It is hoped, if this dissertation is published to provide a framework for more research in this area of freight AV. The dissertation could be used as a persuasive tool to encourage political figures to implement changes to current laws and action new policies to embrace freight AV. Ireland may not have an industry to manufacture vehicles, it does however, have a large number of high level technology and research companies that could assist with current European projects.

**3.4.6 Conclusion**

Mingers’s framework provided a structure that is open to including additional methodologies as appropriate to the topic being researched. As inexperienced researchers, they may not, at present, be versed in many approaches to research; it does however, still offer future inclusion, as their skills and knowledge grow. As such, the framework is still valid and necessary for the mixing of methods.
Researching multimethodologies has been a challenging experience to understand and appreciate its merits. However, the reward of combining research has the potential to have greater impact on the audience. Figures can be used to influence policy-makers and a descriptive rich narrative will create a stronger impression of the dissertation. Additionally, as it will include a wider range of data sources it will reduce the risk of wasting useful information.

As it stands, the chosen framework may not appear to be a fully realised interpretation of multimethodology. Nevertheless, it provides a sound set of guidelines to expand the research by including other methodologies in future developments. Recommendations for future research will be added to the conclusions in chapter 5.

3.5 Chosen Actions

The section below will describe the two methodology actions that were chosen for the dissertation: literature review and semi-structured interviews.

3.5.1 Literature Review

Okoli & Schabram identify three general types of literature review; the first is what they call the “theoretical background” which is the section of a journal article that describes the theoretical foundations and context of the research. The second is the literature review chapter of a student dissertation of thesis and the third is a stand-alone literature review journal article which reviews the existing body of research in field without introducing any new data. The authors make the point that a detailed methodological approach is necessary for any kind of literature review (Okoli & Schabram, 2010, p. 2).

Hart outlines reasons for reviewing the existing research. Some of the points highlighted were relevant to the subject of this dissertation. These included; distinguishing what has been done to what needs to be done, discovering important variables relevant to the topic, synthesizing, establishing context, identifying historical context and acquiring the subject vocabulary (this area was important as none of the project team were familiar with logistics and freight haulage and learning some of the background to the freight haulage industry helped to build credibility when it came to conducting the interviews) and identifying relationships (Hart, 1998). Randolph argues that another purpose in writing a literature review is that it provides a framework for description in the analysis chapter of a dissertation which details how new findings relate to previous research (Randolph, 2009, p. 2).

The paper by Randolph guided the overall approach in performing the literature review. The author draws on Cooper’s Taxonomy of literature reviews (Randolph, 2009, p. 2) who put forward that literature reviews can be classified by six characteristics; Focus, Goal, Perspective, Coverage, Organization and Audience (Cooper, 1988).

Focus
A focus of a literature review could potentially be on research outcomes, research methods, theories or applications (Cooper, 1988). As the subject of this dissertation was related to the possible implementation of emerging technologies in Ireland it was felt that the focus of this review would primarily be on research outcomes and the application of those research outcomes i.e. the research projects in the area of autonomous vehicles, how autonomous vehicles would be implemented in society and the possible implications of that implementation.

Goal
The possible goals of a literature review may be to integrate findings across different studies or fields of research or to critically analyse previous research or to identify the central issues in a
research topic (Cooper, 1988) (Randolph, 2009). As the research into the chosen subject was carried out it was found that the presentation of the big picture to the reader was one of the main challenges in the review. In considering the central question of the dissertation “Is Ireland ready to let robots take the wheel transporting freight?” it immediately suggests several more questions such as; what robotic vehicle research is taking place and how are they going to be introduced? These questions cover many disparate fields which would need to be integrated to present the big picture so that became the main goal of the literature review. However in addition it would also need to be critically analysed whether Ireland was capable of introducing the technology and discuss the possible issues in their introduction.

**Perspective**

Randolph argues that secondary research; literature reviews may, like primary research follow either the qualitative or quantitative approaches (Randolph, 2009). It was observed that this research project was mostly following the qualitative tradition and given the wide-ranging nature of the dissertation subject this approach was carried over into the literature review.

**Coverage**

Deciding on the coverage of the literature review was the most challenging aspect. Cooper as cited in Randolph outlines four approaches; exhaustive, exhaustive with selective citation, representative and purposive (Cooper, 1988) (Randolph, 2009).

An exhaustive review entails locating every piece of research available on a topic while an exhaustive review with selective citation limits the search to certain sources. Given the time and work related constraints on the project team these two options were not viable. The third approach outlined is to take a certain number of papers and use these as a representative sample to make inferences about the entire area of research it that field. The final approach is to take a purposive sample of the most influential papers in the field. As the research subject was about an emerging technology where the body of knowledge published in journals might be limited the approach chosen was to take a representative sample of the available papers in the field and in related fields which were slightly more mature. As much of the research into autonomous trucks and cars was being performed by a selective number of research projects the search was concentrated on papers and reports that discussed these projects. In addition while the area of autonomous freight vehicles is only emerging the fields dealing with ICT technology and Intelligent Transport Systems are more advanced. It was possible to find review papers in these areas that covered the central papers in these fields. This helped assure the team that the representative sample was indicative of the entire body of research.

**Organization**

Randolph outlines that three of the most common ways to organize a review are in the historical, conceptual or methodological formats. The historical format is organized chronologically. As this project drew from different fields this format was not suitable. A second possible approach is to base the review around concepts and the third is methodologically; as the overall dissertation would be organized with an introduction, method, analysis and conclusion. The literature review was developed using a combination of these last two formats. The sections in the review were broken up by themes rather than concepts as this better suited the various areas covered and the overall structure organised methodological. This allowed what was learned in the review to be summarized. The topics were identified by using some of the key areas identified during the initial exploratory research phase and organized using a mind map. Rowley and Slack (2004) suggest that concept mapping is a useful tool for identifying and representing key concepts in a research area and the relationships between them.

The topics initially identified are listed below
Is Ireland ready to let robots take the wheel transporting freight? – Team 8

- Technology in automated transport
- Background and history of automated vehicles
- Main players in Automated truck industry
- Advanced Freight Transport Technologies
- Existing Legal Framework governing haulage and automated vehicles
  - Ireland
  - Europe
  - US
- Legal and Ethical Implications of autonomous vehicles
  - Vienna Road Safety Convention
  - Liability
  - Security
  - Previous issues arising out of the introduction of new technologies in long-haul trucks
- Economic effects of automation
- Automation technology and the workforce in the logistics industry
- Freight haulage industry in Ireland
- Technology Innovation and Automation in Logistics and Freight Haulage
- Trends in freight haulage over the next 20 years
- Papers attempting to guide public policy towards Autonomous vehicles

**Audience**

Cooper describes that there are four possible audiences for literature reviews; specialized scholars, general scholars, practitioners/policy makers and finally the general public (Cooper, 1988). As this is a student dissertation the primary audience is the project supervisor and the examiners. The secondary audiences may consist of other students or people interested in the subject who have access to the report.

3.5.2 Semi-structured Interviews

Interviews are a qualitative method to generate information and knowledge about the phenomenon under investigation using different interview questions (Mojtahed, et al., 2014). Kvale and Brinkmann, 2009 describe the three main types of interviews: unstructured, structured and semi-structured:

**Unstructured:** Where the researcher has a pre-determined set of questions to investigate the research phenomenon. The questions are not fixed as one question can lead to other questions that were not pre-defined, depending on the response from the interviewee. They are more conversational than interviews and are useful when investigating new topics.

**Structured:** Where the researcher has fixed and pre-determined questions that follow a specific sequence. The interviewer cannot add other questions during the interview and the questions are given to the interviewee in advance, generally several days in advance to the interview.

**Semi-structured:** Where the researcher has some questions pre-determined and others might not be fixed. The researcher has the freedom to ask follow-up questions to the interviewee depending on the responses. This type of interview provides a structure for the interview as well as flexibility.

This study followed the seven stages in an interview process according to Kvale and Brinkmann, 2009: thematizing, designing, interviewing, transcribing, analysing, verifying and reporting.

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Chapter 3: Research Methodology
Is Ireland ready to let robots take the wheel transporting freight? – Team 8

Thematizing: where the research question was formulated; Is Ireland ready to let robots take the wheel transporting freight?”

Designing: how the interview questions were formulated. The questions where based on the main research question and the literature review documents. To formulate the questions the following aspects were taken into account as described by Kvale, 2009: Introductory Questions, Follow-up Questions, Probing Questions, Specifying Questions, Direct Questions, Indirect Questions, Structuring Questions, Interpreting Question and Silences.

Interviewing: to establish a rapport. The interviews were carried in a respectful manner. The interviewees were debriefed prior to the interview and were given the appropriate documents to read and fill out as per ethics procedure. Everything that was discussed during the interviews was recorded with the interviewees consent.

Transcribing: The recorded conversations were transcribed for further analysis and reporting.

Analysing: To analyse the transcribed interviews the information was colour coded for pattern identification. The main categories are related to the research question. They were identified from the key areas highlighted from the transcriptions. The software used to help with the analysis of the transcriptions was Excel. Excel was used to create an Interview Baseline Score Card for Autonomous Vehicles Technology (see Appendix 3). This allowed the qualitative information from the interviews to be converted into quantitative information to answer the research question “Is Ireland ready to let robots take the wheel transporting freight”

Reporting: Communicate findings in a scientific and ethical manner in the dissertation document.

For the purpose of this dissertation study semi-structured interviews was identified as the suited mechanism to extract the relevant information to answer the research question. The process involved semi-structured interviews with five influence people in the freight industry in Ireland. Semi-structure interview was chosen because of their conversational manner; creating a comfortable environment for the participants to explore areas they thought was essential to the research. Therefore to achieve a deeper understanding of the question this report attempts to answer.

3.5.2.1 Identification of key candidates

The number of semi-structured interviews sufficed with five candidates because of the characteristics of the haulage industry. This sector is a limited market with a small number of key highly experiences knowledgeable people. The chosen candidates were key influential people within this sector. Their peers regard them as experts in the industry. Freight drivers were not interviewed as it was assumed such interactions would be negative. The focus of the research was to seek the industry knowledge from expert policy makers to answer the research question defined by the themes that were explored to support the analysis of the research topic; Technology, Applications, Social and Economic Aspects and Policy and Legal Aspects.
Table 5 below gives a description of the candidates interviewed during the research.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviewee 1</td>
<td>Member of the management board of two of the largest fuel companies in Ireland. The candidate has extensive knowledge within the freight industry with over 10 years dealing with Road transport matters; overseeing a sizeable number of freight drivers and trucks on behalf of one of the two large companies mentioned.</td>
</tr>
<tr>
<td>Interviewee 2</td>
<td>Member of the management board of one of Ireland’s largest logistics companies. The candidate possesses over 16 years of experience in the industry and is responsible for the management of a sizeable number of truck drivers.</td>
</tr>
<tr>
<td>Interviewee 3</td>
<td>Member of the management board of one of Ireland’s largest freight companies. The candidate possesses 8 years within the industry and is involved in the management of a sizeable numbers of freight drivers and office duties.</td>
</tr>
<tr>
<td>Interviewee 4</td>
<td>Carries a key management role for one of the largest fuel companies in Ireland; as well as representing the company’s interests in other European countries. The candidate possesses industry experience in 11 countries and has lead significant automation projects in Ireland and the UK.</td>
</tr>
<tr>
<td>Interviewee 5</td>
<td>Member of the management board of one of the leaders in Ireland of Bulk Liquid transport. The candidate has vast experiences in business, from small to multinational sized businesses. The candidate is considered to be an innovator and policy maker within the industry and is involved in major projects industry wide.</td>
</tr>
</tbody>
</table>

Table 5: Description of Candidates Interviewed
3.5.3 Ethical Considerations

“Ethical codes and guidelines are a means of establishing and articulating the values of a particular institution or society, and the obligations that it expects people engaged in certain practices to abide by” (European Union, 2010, p. 18).

For the purpose of this research the guidelines from Trinity College School of Science and Statistics (SCSS) were followed. To gather information to support the research semi-structured interviews were identified as the research method. Prior to carrying out the semi-interviews the Research Ethics Application was submitted for approval to the Research Ethics Committee, Trinity College. Once the application was approved, the chosen candidates were presented with the appropriate documentation to ensure their knowledge of the research and any implications that it might represent for them.

The research process was kept in-line with the relevant legislation to the project “Data Protection Acts 1988 and 2003” and College Policy on Good Research Practise.

Corbin & Strauss (2014) identify three key areas for ethical consideration: participants, research and researcher.

Participants: because of the face to face interaction that characterises research; researchers must ensure to acquire consent, maintain confidentiality and develop a friendly environment.

Prior to each semi-structured interview each employer and interviewee was sent the appropriate documentation as per the Research Ethics Committee. Following approval, the semi-structured interviews took place in a confidential and in a comfortable environment for both, the researcher and the interviewee.

Research: the researchers must comply with ethical responsibilities. There are times when the research procedure will require to be altered. However the changes must not interfere with the integrity of the method. The research process must be followed through without taking shortcuts to save time. Researchers must understand their responsibility to punish the results of their research to help generate new knowledge.

Because of the nature of the research technique chosen “semi-structured interviews”; there was some flexibility in this method. The researcher kept the integrity of this method to gather valuable data relevant to the research.

Researcher: If a research project is undertaken, it is the researcher’s responsibility to produce the highest quality work that he or she is capable of.

The research performed an exhaustive study of the research topic. This was used to provide an understanding and give insight into Autonomous Vehicles Technology and the possibility of its application in the road freight industry in Ireland.
Chapter 4: Findings and Analysis

4.1 Introduction

This chapter will present the analysis phase of answering the research question; Is Ireland ready to let robots take the wheel transporting freight?

The chapter structure corresponds to the methodological approach described in Chapter 3 with a Qualitative core comprised of the literature review and semi-structured interviews and a Quantitative supplemental component based on the analysis of the semi structured interviews.

What was learned in the literature review fed into the formulation of the list of questions for the semi-structured interviews and allowed the researcher develop the discussions with the participants beyond the initial questions. The literature review analysis also informs the conclusions and recommendations for further research.

4.2 Literature Review Analysis and interpretation

Randolph outlines five stages in conducting a literature review; Problem formation, Data collection, Data evaluation, Analysis and interpretation and Public presentation which parallel the stages of conducting primary research (Randolph, 2009). In the planning discussions prior to starting the main phase of the literature review the discussions did touch on each of the areas so overall the process described by Randolph was followed.

4.2.1 Analysis and interpretation

In conducting the review the team felt that the best way to present a coherent and instructive picture was to provide as clear a description as possible of the different technologies involved. This would include the background to their development and how they are being implemented in the world today. This would range from the emerging area of autonomous vehicles to the current use of on-truck information systems. In order to provide a rich description the review would need to deal with the legal aspects and touch on the possible wider implications for the road freight industry, government/policy makers, wider economy and society which have a heavy dependence on the industry.

In the preparation for the review in the final report it was felt that some of the topic headings as identified in the planning stages were slightly unwieldy. In the final review phase some of these headings were slightly changed and/or split into different sections in order to follow the main themes of technologies, applications, socio-economic, policy and legal. In addition, the original number of headings was too ambitious given the time constraints of the project. As a result some topics did not make it into the final report. It was felt that the omission of these topics did not affect the overall coverage as they were not crucial to answering the central research question of “Is Ireland ready to let robots take the wheel transporting freight?”

The discussion and analysis of the literature review will follow the four broad themes identified; technology, applications, socio economical and finally the policy and legal aspects.

The review starts with a question; what is an autonomous vehicle? The definition that was chosen from the literature refers to cars but it can also be taken to applying to freight vehicles; an autonomous vehicle capable of fulfilling the human transportation requirements of traditional cars. This basically means a vehicle that can get from point A to point B without the intervention of a human to direct its progress between the two points. In considering this what comes to mind is that in the real world a human making even the simplest journey between two points needs to interact with the world and deal with events. Humans will observe the process and deal with these events.
based on the knowledge and experience that they have gained by interacting with the physical world and other people. The AV making the same journey will interact with the physical world and deal with events using electronic sensors and by communicating with other vehicles and objects in the surrounding environment. A possible implication of this is that AV’s, in order to operate safely may need to be able to communicate with everything else that is in its vicinity or path that is moving and if it cannot communicate with a moving object will need to regard it as a possible threat and act accordingly. A second implication is that all these objects will need to communicate using a common language. This shows that the definition of communication protocols for vehicles will be major stepping stone to level 5 automated vehicles.

The literature shows major advances in sensor technology such as collisions avoidance systems and LIDAR with some high-end cars and trucks already including these features such as Volvo (Martin, 2014). Currently the autonomous driver assistance and safety feature in trucks don’t rely on V2V and V2I communications. It seems likely that over time if the advanced safety features are seen to reduce accidents and have positive effects on the environment it will help AV’s gain public acceptance and will increase the pressure on governments to spend money on upgrading the road infrastructure to include smart technology based ITS systems that will support the V2V and V2I communication. The challenge in this is maybe to convince road hauliers to use the latest driver features. The papers by Zeimpekis and Giaglis (2006), Perego et al. (2011) and Benza et al. (2012) shows that road haulier are willing to invest in ICT when it will provides business value, the OECD Freight Transport report (2012) said that companies will not invest in new technologies based on the public interest and will only invest in sustainability measures if they are forced to by governments. This shows how policy makers can influence the introduction of the new technology.

Aylward and O’Toole (2007) described how ICT was having a positive impact on the Irish road haulage industry but the level of take up was low and not used to improve efficiency to its full potential compared to the UK where the government had made increasing the use of ICT in the road haulage industry part of a strategic plan for transport. In contract a transport report from the Irish government did not mention ICT in the road haulage industry and mostly appeared to be aspirational saying that committees would be formed and further research needed. This was the same report which described Ireland as a “Technology Taker” as regards adopting new transport technologies instead waiting until they are seen to have value elsewhere before considering their adoption (Department of Transport, 2009). While the argument for waiting for AV technology to become more developed may be valid considering the countries’ economic difficulties over the last number of years but taking the same view towards a technology that is already used by some of the leading road haulage companies in the country appears to be overly conservative.

The importance of an integrated ITS system for was discussed by Alessandrini et al. (2014) who argued that future automated freight transport vehicles will need an ICT infrastructure to operate safely and efficiently. Pagano et al. (2013) described how the current ITS systems was identified by the EU commission as a weak point in the European transport network as had been one of the areas prioritized in the EU Directive for the deployment of ITS in Europe.

The literature showed that ITS related research projects taking place across Europe over the last five years. Many of these are in the areas of vehicle communication and co-operation with the aim of increasing road safety or sustainable transport. In addition many of them appear to have received funding from governments and/or the EU. What is apparent in the examples included in the literature review is that nearly all of them are concentrated in the main car producing countries; France, Germany, Italy and the UK. These last points suggest two things; the first, unsurprisingly is that the issue of road safety and sustainable transport are two of the key factors behind the move towards more automation in vehicles from a government policy perspective. Many of the papers about AV and ITS claim in one form or another, that their introduction will make travel safer and
more energy efficient Pagano et al. (2013), Yoshimoto and Nemoto (2006), Papadimitratos et al. (2009).

4.3 Semi-Structured Interviews

Each interviewee was informed the interview process was a semi-structured interview. Set questions were developed however the interview questions were only used to provide guidance to steer open conversations between the research team members and the interviewees. The main discussion points that arose from the interviews included; the impact of this disruptive technology; workforce and changes to follow, autonomous technology advancements within haulage vehicles, knowledge of autonomous technologies within the industry, legislation; previous examples of barriers to introducing new technologies and bureaucracy for implementing changes, public acceptance and advantages of AV Technologies; Safety, Economy. The section below will provide an analysis of these points.

Interviewees had varied degrees of knowledge, opinions and observations pertaining to the research topics of AV technologies presented below. The section below contains synopsis developed from the transcripts from the interview process under the topic headings we have chosen to analyse in order to answer our research question “Is Ireland ready to let robots take the wheel transporting freight?” The synopsis are then interpreted to reflect on what the interviewees have said about each area to build further knowledge for the purpose of this study and possible areas for future research.

4.3.1 Data Analysis

1. Interviewer Knowledge of AV

All interviewees demonstrated familiarity with AV technologies with different levels of knowledge and expertise shown among the interviewers. The analysis of both the interviews and literature review links a broad spectrum ways of how autonomous technologies can be introduced. The car market is increasingly introducing autonomous technologies into vehicles such as lane departure warning and parking assistance, whereas within the haulage industry projects such as platooning and the COMPANION project are investigating various ways and levels of automation options for the introduction of automation into the haulage industry.

**Interviewee 1** – Had an awareness and knowledge of AV’s but did elaborate during the interview process of examples of AV’s

**Interviewee 2** – The interviewee was familiar with autonomous technologies having seen demonstrations within the mining industry of autonomous vehicles in operation. The interviewee was very impressed by the technology advancements, however acknowledged these particular operations were safe guarded in a quarry and not on public roads. The interviewee discussed that advancements to technologies was increasing within the haulage industry for example “vehicles reading the road and mapping the road, so when the driver does the route first time, the vehicle will remember, so the next time the driver takes the route, automatic change gears in hills, it will reduce the drag and cornering so the advances are there”.

**Interviewee 3** – Mentioned he saw a demonstration of the Mercedes truck driving on its own and was very impressed with the level of advancements. “The driver controls the vehicle and all of a sudden he presses a button and the seat goes sideways and the driver gets comfortable playing on his tablet”. He mentioned from the technology and from the vehicles point of view he thinks the technology is there.
Interviewee 4 - Has extensive knowledge and exposure to AV technologies. Participated in trials in the advanced transit link Rotterdam project and led vehicle depot automation in UK and Ireland. Also feels the autonomous vehicle technology has rapidly advanced and is ready however sociologically and politically we are not ready.

Interviewee 5 – Has seen the benefits of automation within industries such as manufacturing facilities and greatly understands the benefits of this technology. He is aware of the technology and is closely monitoring advancements to improve operations.

2. **Irish Infrastructure for AV, Ready?**

All interviewees were consistent with the view that Ireland has not looked at the Irish road infrastructure in its current form to allow autonomous vehicles on Irish roads. Conversed autonomous vehicles could be introduced into Irish road infrastructure between two fixed points where possibly a segregated lane for AV’s is available. From the research conducted during this dissertation, this approach would coincide with how other countries are slowly introducing autonomous vehicles into public realms. Some examples are the self-driving Park Shuttle system in Rotterdam and the Ultra Pod passenger carrier at Heathrow airport. Proposals were discussed in the interviews of possibilities for Ireland to Introduce AV’s onto Irish roads. An example of such a possible approach is summarised in recommended future research in Chapter 5.

Interviewee 1 – From the road infrastructure point of view and from the compliance point of view believes there hasn’t been any significant work done, essentially not in Ireland as far as he is concerned. "I think the vehicle technology is there but regarding the infrastructure in Ireland there would be a lot of work to be done”.

Interviewee 2 – Compared Ireland’s infrastructure readiness to the UK’s by the development of growth maps. Opinion is Ireland is way behind infrastructural capacity to introduce AV referring to Ireland’s lack of growth maps in comparison to the UK.

Interviewee 3 – Mentioned the road infrastructure has greatly improved over the last number of years with the route from Dublin to Cork now 95% motorway. This provides a great opportunity for both road trains and the introduction of AV’s onto Irish roads.

Interviewee 4 - Described how AVs using a dedicated infrastructure has been a success in Rotterdam but there are huge challenges getting kind of transportation projects completed in Ireland due to the involvement of so many stakeholders.

Interviewee 5 - Also described the difficulties in implementing innovative developmental projects in Ireland, also cited a very conservative approach from stakeholders towards innovation in transport and a long planning cycle.

3. **Government Policy for AV, Ready?**

From the interviewees opinion it can be deducted that from a governmental perspective, it is highly unlikely that Ireland will become a leader in the introduction of AV’s. The level of governmental bureaucracy alignment to support AV’s will be a challenge.

Interviewee 1 – Discussed how policy changes are initially welcomed but fall down at the final hurdle at the decision making stage. “When the obtaining of a signature to implement such a change is required there appears to be a reluctance to be held accountable”. Believe Ireland will not lead the way for autonomous vehicles but will be followers. “I’ll tell we will be followers, if we see it
working somewhere else, I would say that would be fine. It will be very difficult to become the experimental place”.

**Interviewee 2** – Discussed the challenges AV introduction would face due to government agencies and policy makers not aligning to support new initiatives and developments. Spoke of knowledge of a previous application for a road train project into Ireland that had considerable benefits to reduce fuel emissions, carbon footprint, costs and safety. The licence was in theory passed but did not gain all authority approvals and was subsequently abandoned.

**Interviewee 3** – “because of the significance of the change it has to be driven at a government level and in terms of the scale of the business in Ireland probably the cost of introducing this, in terms of the savings, in the short term it might be prohibited”.

**Interviewee 4** – Reiterates interviewee’s comments referring to the challenges to get government backing to introduce AV’s “Ireland tends to have a very long planning cycle here and is open to democratic challenge at multiple stages. The British planning cycle has a single step in the field, whereas here we have multiple steps. We have local authorities; we have An bord pleanala steps, the courts, so it tends to be much slower. You could argue that that makes Ireland fully democratic but if you are trying to do something or in your case trying to predict whether the infrastructure will ever happen”.

**Interviewee 5** – Believes to introduce AV’s into Ireland will require a strong champion “introducing autonomous vehicles into Ireland you would need a strong champion and even with that you would still experience a lot of blockers barrier associated with any developmental project and that will effect Ireland to progress with introducing Autonomous vehicles in this area. There needs to be a different way of getting important projects through the system. The system that is currently in place for granting approvals at any sort of level is torturous”.

### 4. Legal Framework for AV, Ready?

The literature review indicates Ireland has not taken any steps in anticipation for AV technology. Former Irish minister of transport Leo Varadkar said “It is absolutely the case that technology is ahead of legislation, but it is very hard to write legislation in anticipation of technologies that might or might not develop” (Irish Times, 2014). It can be observed that the interviewee’s opinions are consistent with the findings in the literature review. No evidence was found of Ireland’s legal preparedness to be leaders in introducing autonomous vehicles.

**Interviewee 1** – Talked about how the big companies were getting support from governments for their research projects but in Ireland it is difficult to get projects off the ground, he described how his company had pushed for legislative changes for the research project also mentioned by interviewee 2 which in the freight transport area but without success due to licencing issues.

**Interviewee 2** – Spoke about legal challenges to any large infrastructure project in Ireland can be an arduous process that can take years to bring to completion.

**Interviewee 3** – Alluded to a research project that his company had tried to get off the ground but without success in that instance.

**Interviewee 4** – Spoke about long planning cycles inherent in getting large scale development project completed.
Interviewee 5 – Discussed the legal framework would be driven by the technology and that the likelihood is it would be a large multinational through marketing campaigns would push the demands that would see a knock on effect to the legislation. “The likes of google will have a greater influence to bring these projects to light. It is going to be the technology that will drive this, it will all come together from the commercial aspect and the frameworks will follow suit by the studies developed by the EU but will require the big commercial companies to bring it down the line. A total different level of force behind it, it’s all down to marketing and delivering this”. Believes in order to introduce AV’s into Ireland and into the legal framework would require strong political lead “Political willingness is one thing the issue is the civil servants ready? And that is a different issue than political because they may shuffle this around from one department to another that could possibly block it, well not overtly block it but are quite likely to actively avoid making decisions. So unless you have a very strong political lead”

5. Are Autonomous Vehicles Safer?

During the process it was interesting to see the 360 degree turn within the interviews with regards to safety. The interviewees explored more the safety aspects of autonomous vehicles to human driving. When comparing human to autonomous all interviewees had a change of opinion in support of AV technologies would be safer.

Interviewee 1 - One of the biggest risks that we are trying to prevent is roll overs. And that would probably be where automation will be able to sense because it is sensor based.

Interviewee 2 – When discussing the safety features of autonomous driving to manned driving the interviewee mentioned “the autonomous vehicle would actually react and break quicker than you, there is actually no hesitation about that, it will respond and react quicker”.

Interviewee 3 – The interviewee was not convinced of the safety features research has provided in relation to AV’s. “The research that is carried out so far, I think, I don’t think is accepted largely”.

Interviewee 4 – Opinion is AV’s are safer with no hesitation. “Removing the human element from any operation will make it safer”

Interviewee 5 – Based on his long experience within the industry the interviewee would not say whether he thought AV’s were safer until he saw hard evidence the technology was advanced enough. The interviewee was non-committal but mentioned public acceptance and said he believes the technical problems will be overcome. From his perspective he can see the potential including improved safety but public acceptance is the issue.

6. Public Perception of AV

The analysis of conversations throughout the interviews suggests slow introduction of autonomous vehicles will allow the public to adjust to the change. This literature review is in agreement with this opinion. It was found that the public tend to be the most resistive to change, especially when they are affected directly.

Interviewee 1 – “I think there is as much concern as much emphasis need selling to the public, as there is fir tit to be introduced. If the research is done and presented in advance or something taken to the road and well publicized on a trial basis I think you would be surprised of the buy in you might get”
Is Ireland ready to let robots take the wheel transporting freight? – Team 8

Interviewee 2 – “I think there is as much concern as much emphasis need in selling to the public, as there is for this to be introduced. If the research is done and presented in advance or something taken to the road and well publicised on a trial basis I think you would be surprised of the buy in you might get. Because curiosity would say I want to see this in operation and if you have demonstrators available to partaken. I think it is about selling it to the audience. It is a product that has to be sold and get people’s buying in and trusts back”.

Interviewee 3 – The interviewee was sceptical the public would be convinced of the safety of AV’s, “The research that is carried out so far, I think, I don’t think is accepted largely. When you mentioned that it has been proven that it’s safer I don’t believe that is the wider perception”

Interviewee 4 – Believed the introduction of AV’s would need to be slowly introduced onto Irish roads by point to point routes with no third parties on roads. His opinion is “All change is met with resistance”.

Interviewee 5 – Feels this would be a challenging area for the introduction of AV’s. Opinion is cars will need to be introduced firstly to gain public acceptance. “It would first have to happen with cars before it gets public acceptance. I have been following the arguments in the press, how does the autonomous vehicle make an ethical choice. If there is a decision that involves loss of life the human brain can calculate that can the autonomous vehicle. This was somebody making the argument against the AV in the UK.”

7. Freight Driver Perception of AV

The research team concluded in hindsight a survey of drivers opinions of autonomous vehicles would have been useful as from our literature review this is lacking in existing research. The candidates chosen for interview had minimal direct dealings to gauge a good understanding of the thoughts of freight driver’s opinions of AV’s. The research team would suggest this is an area for future research.

Interviewee 1 - The interviewee did not have any direct dealings with freight drivers therefore could not provide an informed opinion of their perceptions of AV implementation

Interviewee 2 – When discussing the introduction of autonomous technologies into freight vehicles the interviewee discussed freight drivers concerns “Drivers are very worried, they see it as an extension of when the LUAS was introduced; third parties were the biggest problem. The amount of people colliding with the LUAS, that really is what worries drivers, what are people’s actions? Will there be a dedicated lane? Will there be safe wards put in place actually structured; Separate lanes, especially when you have heavy goods vehicles”.

Interviewee 3 – The interviewee did not have an opinion to driver’s perception of AV’s.

Interviewee 4 - The interviewee did not have any direct dealings with freight drivers therefore could not provide an informed opinion of their perceptions of AV implementation

Interviewee 5 - Interviewee spoke about the difficulty of getting younger people to join the profession. It would be interesting to explore in later research if the thinking among management is that AV tech would change the profile of the profession making it more of a knowledge worker role

8. Would Costs in Freight Transport be reduced if AV was adopted?

Analysing the different opinions it is striking how much benefits the interviewees could see on the introduction of AV. This can be taken as a good sign from the technology implementation point of
view. It would appear that once the legal framework, legislation and infrastructure is in place; companies would take the steps necessary to embrace such changes because of the possibilities it provides to them.

**Interviewee 1** – “The running costs would be substantially lower, heavy weight foot and poor break would be eliminated which will contribute to fuel efficiency”. Now with automation, the truck downtime will be reduced which is an incredible thing. The more and more you can take the human element out of operation, the more efficient it will be”.

**Interviewee 1** - Vehicle utilisation within haulage was around 70 percent. This is down to your planning to facilitate your drivers’ shifts as such, so you are taking the man power complication into account. If you think about it, if we had at autonomous vehicles, the vehicles would be running 24/7 only with break for maintenance. **Interviewee 3** agreed the benefits of vehicle utilisation can be greatly achieved by AV technologies “by knocking a truck out of the system you would get a return on investment in a year just by automating”.

**Interviewee 2** – “the first thing that would strike me straight away is that the fact of a driver using cruising control the whole time, means your fuel saving would be incredible because it will only use the fuel it needs it won’t be using estimating and assessing like a driver so it knows what it needs”.

“I think it would have positive effects even on routing and scheduling because it’s an automated system so it would naturally be making sure that if there is a vehicle that is going somewhere

**Interviewee 3** - from managing the operations point of view it is a fantastic solution because vehicle utilisation point of view, from resources management point of view again, costs, wow the possibilities are endless, and again, you are taken out the driver error element when it come to the driving, it’s much safer, which is brilliant.

**Interviewee 4** – Spoke of the shortage of experienced drivers available within the industry. This is a concerning trend and autonomous vehicles will rectify this.

**Interviewee 5** – “In the last number of months it has got quite difficult in Ireland and there is a serious shortage of drivers in the south of the UK. The London area is very difficult to recruit drivers. For a variety of reasons there is not a big driving pool as there was so I think that also helps the case for autonomous vehicles”. The interviewee also stated that the drivers for the introduction of AV’s are the “drivers and costs generally will be the biggest economic driver for AV vehicles”.

9. **Would Freight AV be safer than current drivers?**

There was a noticeable awareness on the interviewees side regarding safety risks associated with human error, drivers fatigue and loss of concentration were notable factors. There was strong opinion that autonomous vehicles would be a safer replacement to human drivers. This can be argued further as so far the technology has only been tested in controlled environment with small interaction with third parties on the road, as revealed in the literature reviewed.

**Interviewee 1** – One of the biggest risks that we are trying to prevent is roll overs. And that would probably be where automation will be able to sense because it is sensor based.

**Interviewee 2** - the autonomous vehicle would actually react and break quicker than you, there is actually no hesitation about that, it will respond and react quicker.

**Interviewee 3** – Discussed 24/7 operations for drivers and shift work where a study was conducted that highlighted the known factors associated with body clocks and driver fatigues. Also how driver
complacency can impact drivers performance. This led to the interviewee’s assumption AV would be safer than current drivers.

Interviewee 4 – Believes AV’s would arguably be safer referring to the current safety concerns of haulage drivers. “In fact the biggest concern in terms of port tunnel is driving losing concentration and hitting a side wall. An AV won’t do that. If it loses control or signal it will stop. We have had accidents like this before because of concentration issues”.

Interviewee 5 – Discussed the significant safety benefits to road trains by better vehicle utilisation of vehicles would reduce the amount of trucks on our roads. “Road trains would certainly go some way towards Ireland meeting our Road transport Kyoto requirements. It is more efficient from a financial point of view, takes up less road space, it is safer”. Did not have a direct opinion on whether AV’s would be a safer alternative.

10. Is Freight AV technology ready?

The technology readiness is fast advancing similarly to cars haulage vehicles are adding more sophisticated technologies in assisting drivers. The literature review section outlines the advancements within the technologies and the main player leading the way. The interviews supported this in that the technology will not be a blocker to AV’s.

Interviewee 1 – “I think there inevitably AV is on the way, it’s a matter of when”.

Interviewee 2 – We use fleet board as our telematics system, which is owned by Mercedes. Mercedes have this system in their trucks but it can be bought separately and place it in other trucks. We have Renaults and Mercedes trucks in our fleet. “The technology is there is how to implement it”.

Interviewee 3 – “I think the vehicle technology is there but regarding the infrastructure in Ireland there would be a lot of work to be done. You would need to paint the roads with a special paint and a magnetic coating which allows the vehicles to stay within the lanes. We already have lane assistance; if somebody had said this to me 15 years ago I wouldn’t have believed it.

Interviewee 4 – “If you look at the history and you look at the vehicles, you started off in the 70s with tachografts and that was the first step to bringing automation into the vehicle cabs. You gradually get more and more automation, you get GSM tracking, your get routing information and the next logical step”.

Interviewee 5 – States that “the likes of google will have a greater influence to bring these projects to light. It is going to be the technology that will drive this, it will all come together from the commercial aspect and the frameworks will follow suit by the studies developed by the EU but will require the big commercial companies to bring it down the line. A total different level of force behind it, it’s all down to marketing and delivering this”.

4.4 Quantitative Analysis of Semi-Structured Interviews

This section will quantify the qualified data. By doing so, it will create a baseline target for future research into freight AV in Ireland.

To retain an objective point of view one researcher, who did not take part in the interviews, will examine the transcripts. The researchers will design a score-card using MS Excel to record measurable data. Using important key information from the transcript, they will create headings
within the score-cards for each interviewee. Each heading will be based on assumptions that will be of interest to the dissertation and highlight new discoveries revealed from the interviews.

When the score-cards are ready they are sent to the research team to review the transcripts and rate/score under each heading based out of a possible score of ten. The researchers will test the transcripts providing, in their opinion, an appropriate rating for each heading. They are provided with instructions to follow when testing.

The research team will conduct the test independently. They will rate each Interviewee on a scale of out of ten under each heading, were the current baseline is set at five. Above five is considered a positive response and below five is a negative response. If the interviewee did not offer an opinion or an assumption or failed to respond to the question then the researcher should use a baseline score of five. As this is the first iteration of this test the baseline can be altered if anomalies are revealed.

When each heading has been scored, it is returned to be graded. The scores are tabulated and will be used to project a five year forecast based on assumed adoption of AV in the Irish freight industry. Each year the forecast will be used as a baseline for testing. It can be assumed that there will be a 15% increase each year in support of AV freight on Irish roads. Conversely, it can be assumed there will be negative instigation from media sources which will impact on public opinion by 10% every two years. These adjustments will help shape the quantitative data over five years.

A 15% increase in favour of freight AV each year is assumed as greater awareness from other projects in the USA, Europe and Asia gain traction. It can be assumed that increased safety, cost benefits and adoption in other countries will have a positive effect on business owners, politicians and the public in Ireland.

A target of 80% will be used to achieve a point of early adoption. This assumed target will be reviewed each year over the course of five years to determine Ireland’s readiness to adopt AV within the freight industry. It is assumed that at the target level that AV would not yet be adopted but would be an indication of a change in perception and adoption readiness.

4.4.1 Interviewees Knowledge of AV technology

Table 6 shows the level of knowledge of the interviewees towards AV technology, especially related to the freight industry and the possibility of introducing AV technology into Ireland.

As a collective the chosen selected interviewees have a strong knowledge in the Irish freight industry and freight AV technology.
Table 6: Interviewees Knowledge base of AV technology
4.4.2 Quantitative interpretation of interview questions

Reviewing the transcriptions and interpreting the data the following scoring was created as shown in Table 7. By analysing the transcripts relevant headings where pulled to support the qualitative narrative. It will also provide a baseline to project a hypothetical five year timeline for Ireland to adopt freight AV.

Table 7: Quantitative interpretation of interview questions

<table>
<thead>
<tr>
<th>1 - No knowledge or opinion</th>
<th>5 - Baseline</th>
<th>10 - Strong Knowledge</th>
<th>&lt;5 - Negative Knowledge</th>
<th>&gt;5 - Positive Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irish Infrastructure for AV, Ready?</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Government Policy for AV, Ready?</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Legal Framework for AV, Ready?</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Are AVs safer?</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Public Perception of AV</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Freight Driver Perception of AV</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Would Costs in Freight Transport be reduced if AV was adopted?</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Would AV be safer than current drivers?</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Can AVs be implemented into Ireland now?</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Is AV technology ready?</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 7: Quantitative interpretation of interview questions
4.4.3 Hypothetical timeline of adoption of freight AV in Ireland

By devising a baseline the investigator can calculate a hypothetical adoption timeframe. This will be used to measure if Ireland is prepared to adopt AV. The average score of each interviewee under the headings of Table 7 will be used to set the baseline for the five year projection shown in Table 8.

![Hypothetical timeline of adoption of freight AV in Ireland](image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>53</td>
</tr>
<tr>
<td>Year 2</td>
<td>60</td>
</tr>
<tr>
<td>Year 3</td>
<td>64</td>
</tr>
<tr>
<td>Year 4</td>
<td>67</td>
</tr>
<tr>
<td>Year 5</td>
<td>77</td>
</tr>
</tbody>
</table>

Table 8: Five Year Projection to adopt AV in Ireland

4.4.4 Baseline timeline for preparedness and adoption of freight AV in Ireland

Table 7 shows a possible timeline for Ireland to consider adopting freight AV. With the baseline set at year one, we can see by year 5 Ireland has not reached the target of 80%. Ireland would not be in a position to adopt freight AV. An additional push by political figures and changes in government policy would need to be changed to have a significant effect on bringing AV technology to Ireland.

![Baseline timeline for preparedness and adoption of freight AV in Ireland](image)

Table 9: Baseline timeframe for Ireland to begin adopting freight AV
4.4.5 Data Analysis using mix method approach

By mixing qualitative and quantitative research this dissertation increased the depth of knowledge and understanding of the topic. It provides a framework for further exploration within this area by being able to incorporate other methodologies. It could be argued that the quantitative data could be biased by the investigator. However, the data evaluated isn’t a de facto map for Ireland to adopt AV but a hypothetical assumption related to similar projects happening in Europe and around the world.
Chapter 5: Conclusions and Recommendations for further research

The purpose of this study is to explore the readiness of Ireland to embrace the implementation of AV in the road freight transport industry. To examine this topic the research explored the four themes identified in Chapter 1: AV Technology, AV Applications, AV Social and Economic Aspects and AV Policy and Legal Aspects.

To answer the question of this dissertation “Is Ireland ready to let robots take the wheel transporting freight?” this section will provide conclusions in each of the different themes stated above and will give a final answer to the question regarding Ireland’s readiness to embrace AV technology in this industry.

5.1 AV Technology Readiness

The literature examined demonstrated great advances in AV technology. It can be perceived that AV technology is in continuous development with an increasing number of technologies available to assist the driver. The papers researched covered different areas in driving automation. There is consistency in the view that existing AV technologies provide assistance to the driver; however there was no evidence found of existing technology that eliminates the need for the driver. The existing publications coincide with the projection that AV technologies for fully autonomous vehicles trucks will be ready from 2020.

No literature was found that provided details of existing AV technology development in Ireland. During the research process it was observed that the countries involved in the development of such technology were vehicle manufacturer countries, for example: USA, Google; Germany, BMW; Germany, Mercedes; Germany, Audi and Sweden, Volvo.

5.2 AV Applications Readiness

The research available is consistent with the fact that AV technology for fully autonomous vehicles has not been applied in uncontrolled real environments. So far the literature published shows the application of the technology has only been used for testing purposes. It is observed that there are a small number of US states that have taken the first steps to carry out tests of such technology with California, Nevada and San Francisco taking the lead. However, it is noticeable that the number of countries interested in the technology is increasing; with countries like the UK, Japan and China being open to the testing of the technology.

The current research in AV technology in trucks doesn’t seem to be as widespread. So far the only industry that has taken the lead in implementing fully autonomous trucks is the Mining industry. Driverless trucks were introduced in the mining industry in 2008.

The data available on the application of AV technology in Irish freight is limited. It can be observed that advancements in ICT are having a slow impact on Irish freight companies compared to other countries such as the UK. There was no literature available to demonstrate the application of fully AV technology on the Irish freight industry.

The papers reviewed were consistent with vehicle “platooning” as an efficient way of operating autonomous vehicles. Looking at the SARTRE and COMPANION projects it can be observed that there are a number of flaws with the method “Platooning” of driverless vehicles. How does the driver of the vehicle in-line know that the lead driver is experienced? Could the driver have prior collisions? Should this information be relayed to the convoy prior to entry? It can be argued that the success of platooning should only be used for freight vehicles. Ümit Özgüner, a professor with Ohio State University’s Center for Automotive Research, predicts that the first wave of operational autonomous vehicles will be devoted to long-haul deliveries. One driver could lead two, three or
more following freight vehicles to their destination. If there were two drivers taking turns leading the convoy it would be able to travel greater distances without rest. This too would reduce accidents which involves sleep deprivation.

### 5.3 AV Social and Economic Aspects Readiness

Throughout the research it was perceived that autonomous vehicles will be facing possible issues relating to public acceptance as well as legal constrains. Research shows there could be a great concern from the public as driverless vehicles would eliminate many professional driving jobs.

The documentation agrees on a major problem facing the haulage industry internationally and that is of a shortage of drivers. It can be seen that even though the industry has tried different strategies to resolve the issue; the problem persists.

Authors argued that automation can have negative effects on human operators; for example the worker may lose the skills to operate the machine or vehicle if called upon to do so in the case of a failure of the autonomous system or encountering a situation that the autonomous system was not able to deal with. Another negative effect may be where the operator has misplaced trust in the autonomous system (SHERIDAN, et al., 1983) which in the case of automotive vehicles may have safety implications.

Another concern that was raised in the papers was the increased reliance on IT, resulting in adverse impacts that traverse international boundaries. These include; increasing complexity and interconnections between critical infrastructures, the just-in-time model that operates in many industries resulting in less operational buffer and finally increased potential accessibility for hostile actors to critical infrastructures (Longstaff, et al., 2000)

The adoption by road hauliers of on-board ICT systems illustrates the trend towards the gradually increasing use of automation in freight vehicles. It is observed that ICT is allowing logistics companies to innovate through the incorporation of ICT systems into their fleet that allow them to provide new services to their customers.

### 5.4 AV Policy and Legal Aspects Readiness

Research shows that the USA and the EU have taken steps to update the legislative and regulatory framework to introduce ITS into the transport systems. It is observed that EU policy recommendations may eventually become incorporated into directives. However EU member governments may or may not sign-up to or else some may become EU regulations.

It is evident from the advances being made into autonomous vehicle technologies that the readiness of the technology will not be the barrier to this innovative technology. What would appear to be the barrier are the legal and regulatory frameworks in place in order to allow the testing and operation of autonomous vehicles.

As a member of the EU, Ireland is bound to European legislations. The Road Traffic Act and Road Transport Acts will need to be amended to allow the testing and future developments of automated vehicles. Throughout the review of the existing literature no evidence was found to show that Ireland is preparing for such a review of its current legal framework in anticipation to autonomous vehicles. In fact Ireland appears to be overly conservative about supporting new innovations in the area of freight transport.
5.5 Is Ireland Ready to let Robots take the wheel Transporting Freight?

During the research of this dissertation it was found that there are elements of AV technology in the freight industry. These technologies are to assist the drivers and increase efficiency in the management of the industry operations. However, no evidence was found that shows Ireland is ready to embrace such technology in the road freight industry. The findings and analysis of the literature review and semi-structured interviews shows Ireland is not in a position to introduce such technology and so the answer to the research question is a definite “no”.

5.6 Recommendations for Future Research

During the research of this project, possible areas where AV technology could be introduced into Ireland were identified. Due to time constraints it was not possible to thoroughly explore these options. This section gives an overview of recommended future research in application of AV technology.

5.6.1 Should Autonomous Trucks be implemented only where a dedicated or enclosed infrastructure exists?

Rijsenbrij et al. (2006) argue that while automated trucks mixing with normal traffic is technically possible issues relating to public acceptance and legal constraints mean that a dedicated or enclosed infrastructure needs to be used. This raises the question as to whether autonomous trucks should be implemented only under such conditions. Further research would need to be carried out to prove the validity of this statement.

5.6.2 Can AV solve the shortage of drivers issue in the freight industry?

One periodical from 2014 argued that the driver shortage was being overstated and government data showed that the number of smaller carriers was increasing as the economy recovered (Berman, 2014). This poses the question of whether the core problem is the existing industry capacity as dictated by the prevailing business climate and if so whether autonomous vehicles could solve that problem. This is a question that should definitely be investigated in later research.

5.6.3 Do autonomous freight vehicles mean catastrophic failure?

Longstaff et al. argued that the increased reliance on IT has resulted in adverse impacts that traverse international boundaries. These include; increasing complexity and interconnections between critical infrastructures, the just-in-time model that operates in many industries resulting in less operational buffer and finally increased potential accessibility for hostile actors to critical infrastructures (Longstaff, et al., 2000). In the context of autonomous vehicles and advanced ITS infrastructure it is likely to be a some years at least before they would be widespread enough that the kind of failure outlined would cause the disruption described above. Both the national government and also the EU will need to take these risks into account when defining policy for the adoption of autonomous freight vehicles. This is an area which will require further research.

5.6.4 Can professional driving companies survive the rising of AV?

The research highlights that autonomous vehicles is on the way. Even though driverless vehicles are not in existence at the moment in urban real environments, it can be concluded that the technology is coming. There are many industries that could be facing the challenge of how to adapt to such changes. Taxi companies, courier companies, bus companies, trucks companies are some of the areas where autonomous vehicles could disrupt first. A study should be carried out to explore if such companies can embrace these changes and survive or would it mean the closure of all these businesses.
5.6.5 AV as an alternative to a Pipeline in Dublin

The semi-structured interviews conducted as part of this research disclosed an area for possible future research for the introduction of AV's in Ireland. A proposal to investigate the feasibility of an autonomous vehicle track in comparison to an aviation pipeline was discussed in detail. The research team agreed due to time constraints it would not be possible to fully investigate this option. The following is an overview for potential further research.

By conducting a comparative review of the proposed aviation pipeline submission by the Independent Pipeline group and the proposal of an alternative option; autonomous vehicle implementation for the transportation of aviation fuel from a set start to end point namely, Dublin Port to Dublin Airport. The proposal was selected based on the route having a high traffic density, short distance continuous route with minimal third parties obstacles such as humans or animals. The review would compare autonomous haulage to the study currently under review for the aviation pipeline based on factors such as safety, costs; operational and capital, regulatory and legal requirements, timing scheduling, proposed routes and alternative route, public acceptance and consultation.

The review would explore the feasibility of autonomous technologies along the pre-selected route. This will be studied as a possible consideration to deal with the immediate requirement to address the unsustainable current infrastructure for meeting aviation demands at Dublin Airport. The use of autonomous transport could be explored as an alternative option to an underground pipeline for the short-term. The analysis will allow further investigations on what will be required to introduce autonomous vehicles into Ireland. This review could also assist researchers in exploring the challenges that may present itself in the introduction of autonomous technologies into Ireland’s road infrastructure.

5.7 Lessons Learned

The research team worked closely together to write this dissertation. The team developed a strong bond through the process. The researchers improved their time management skills and learned to work to deadlines. The ability to research a topic requires patience, logic and determination. Knowing what to use and what to discard is a skill in itself. The team learned the importance of following theory and how to apply it to the topic. The team developed questions to conduct an interview and how to tease out the important information and keep the candidates on topic.

“Always be prepared” is the team’s new moto. During one of the interviews two members of the team had agreed to record the meeting. Unfortunately one of the recordings became corrupted but luckily the backup recording allowed the team to transcribe the interview.

The team had attempted to use wiki pages for collaboration on the paper. However, its inflexibility, poor speed and performance made work on the dissertation ineffectual. After two weeks it was decided not to continue using it.

The choice of methodologies proved to be a challenging task but by doing so the team learned a new way to approach the world and how to analyse it. When deciding on a methodology the idea of mixing methods was an attractive proposition. However, during the process there was an unsettling feeling that the team’s inexperience may not get to fully explore the possibilities of multimethodology. Upon realisation it was too late to back-track, the team decided to move forward. They created a framework that could be used for future iterations of the dissertation.
Completing this dissertation is a proud achievement; it will shape the researcher’s view of the world. Future projects will appear less daunting, knowing and being able to apply the theory to back up their ideas. This project has provided lifelong skills that will benefit the team in their careers.
### Appendix 1: Dissertation Schedule

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**Key Dates**

- **Submission Date**: Sun 26/05/15
- **Final Approval**: Fri 30/05/15
- **Dissertation Defenses**: Mon 02/06/15 - Fri 06/06/15

**Notes**

- All tasks are to be completed by the specified dates.
- Adjustments to the schedule may be made as needed.
- All tasks are to be submitted in draft form and reviewed by the supervisor.

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**Appendix 2: Research Methodology**

- **External Tasks**
  - Manual Task
  - Finish only
  - Deadline
  - Progress
- **Internal Tasks**
  - External millstone
  - Inactive task
  - Inactive milestone
- **Inactive Tasks**
  - Manual Summary
  - Inactive milestone

**Project Status**

- **Project Summary**: Inactive summary
- **Start-off task**: Finish only

---

**Appendix 3: Results**

- **Methodology**
  - Manual Task
  - Finish only
  - Deadline
  - Progress
- **Internal Tasks**
  - External millstone
  - Inactive task
  - Inactive milestone
- **Inactive Tasks**
  - Manual Summary
  - Inactive milestone

**Project Status**

- **Project Summary**: Inactive summary
- **Start-off task**: Finish only
Appendix 1 (Continuation): Dissertation Schedule

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Research Team
Appendix 2: Semi-structured Interview Questions

1. How many medium and heavy vehicles does your company operate?
2. What is your level of knowledge in the area of autonomous vehicles?
3. Does your company currently use any autonomous vehicles or technology for loading/transporting freight?
4. Have you seen any examples of these technologies, for example at trade shows?
5. Does your company currently use any autonomous vehicles?
6. Does your company currently use any autonomous technology for loading/transporting freight?
7. Is your company aware of the research taking place into autonomous technology such as assisted highway trucking, truck Convoy Systems?
8. The EU has directed that all new trucks and buses need to have an advanced emergency braking systems to Heavy vehicles from 2015. As this technology involves some ceding of control from the driver to an autonomous system, how comfortable are you with the prospect of your drivers giving up control of vehicles to an autonomous system?
9. Do you see barriers in the adoption of these technologies on Irish roads? What are they in your opinion?
10. Do you think whether the experience of introducing and using the advanced emergency braking system in your company’s fleet would make you more open in the future to introducing further autonomous systems when they are made available by manufacturers?
11. Do you see risks or rewards to the introduction of autonomous vehicles technology?
12. If you see risks, what are they?
13. If you see rewards, what are they?
14. When your company is renewing elements of its fleet would it consider paying extra for autonomous vehicles features if they were available?
15. Do you believe that the introduction of autonomous vehicles would provide a good return on investment for haulage company owners?
16. Do you believe truck drivers would be in favour of the adoption of these new autonomous technologies?
17. In your opinion, what are the implications of the implementation of autonomous vehicles in the road haulage industry?
Is Ireland ready to let robots take the wheel transporting freight? – **Team 8**

**Appendix 3: Baseline Score Card – Researcher 1**

Table 10 Individual Quantified Semi Structured Interview results

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Table 11 Average Baseline Score over five years (Rounded to whole number)

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### Table 12 Interviewee Knowledge Score

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### Table 13 Overall Baseline score

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