National College of Ireland

An empirical assessment of technological improvements onboard trains.

An examination of the modern railways continuous efforts to enhance safe rail travel.

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Award	MSc. Management
Name of College	NCIRL, School of Business
Submitted to	National College of Ireland, May 2021

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Introduction

Have you presented/stated the problem or issue which is to be addressed? ✓
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Abstract

The writer attempts to establish whether current research has demonstrated that rail transport is a safe mode of transport. According to studies rail travel is the second safest mode of transport after flying. Improvements in technology and the implementation of multiple safety assisted devices has achieved this position. Incidents such as signals passed at danger, SPADS and train collisions have become less frequent. The purpose of this study is to assess if technological advances in safety related equipment has had a significant impact in increasing safety and reducing risk on the railway. Has there been a reduction in the number of SPADS in the previous twenty years? Many lessons have been learned from accident investigations and these findings have improved organisational regulations and standards.

The development of rail standards ensures that there is conformance and compliance in rail safety, companies like the national transport agency and the commission for railway regulation all play a major role in ensuring that safety is the primary focus for rail travel. The purpose of this research is to investigate the measures implemented by train operating companies, Government policies and other regulatory bodies, to assure safe rail travel. Literature reviews have highlighted the benefits of simulator training, technological improvements and driver assessment.

The author has established that there has been a large reduction in the amounts of signals passed at danger over the last twenty years. Significant investment and improved training have enhanced the safety standards on Irish railways, a similar reduction in the UK and in the EU has also been recorded. The author has formed the opinion that rail travel safety has improved in the previous 20 years and including the reduction of SPAD related incidents both in Ireland and UK and Europe respectively. The methodology used to interpret the data from the questionnaire, points to a much stronger emphasis on safety standard implementation and compliance with safety standards.

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Acknowledgements

Many thanks to Gemma Davis (NCIRL), for her guidance and support throughout this process, without whom this would have been a very different dissertation.

Thanks to Margaret for her support and assistance throughout the MSc.

Thanks to Cory for his helpful guidance from the library in NCIRL.

Thanks to all of the research participants who gave their time willingly and generously to make this dissertation possible and complete. To my work colleagues who supported and encouraged this work.

I would also like to thank all my family and friends for their encouragement.

I would like to gratefully recognise the support of my wife Edel, for her patience and proof reading along the way. To my children who encouraged and supported me throughout.

Glossary

AAS	Automatic alarm system
ALARP	As low as reasonably practicable
ATC	Automatic train control
ATO	Autonomous train operator
ATP	Automatic train protection
AWS	Automatic warning system
CAWS	Continuous automatic warning system
CBTC	Communications based train control
CCTV	Closed circuit television
CMO	Chief medical officer
CMS	Competence management system
CRR	Commission for railway regulation
CTC	Central traffic control
DART	Dublin area rapid transport
DM	District manager
DMU	Diesel multiple unit
DRA	Driver reminder appliance
DSD	Driver safety device
DTE	District traction executive
ERTMS	European rail traffic management system
ESR	Emergency speed restriction
LED	Light emitting diode
LRA	Low rail adhesion
NTS	Non-technical skills
OTDR	On train data recorder
PIC	Person in charge
PSM	Passenger services manager

PSR	Permanent speed restriction
RPD	Recognition primed decision model
RSP	Railway safety programme
RU	Railway undertaking
SCC	Safety critical communication
SCE	Safety critical equipment
SIM	Simulator
SMS	Safety management system
SPAD	Signal passed at danger
SRG	Safety review group
SST	Stop signal test
TC	Traction control
TOCs	Train operating companies
TSR	Temporary speed restriction
TW	Track worker
VDU	Visual display unit
WB	Warning board

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Research questions.

This dissertation assesses how technology improvements helped the role of a driver and how they perceive safety now. Are there limitations or expectations that are not met? With any safety critical role, it is imperative that drivers are trained for any scenarios in their position. The goal of having SPAD free driving is paramount for railway operators. When a train driver fails to respect a signal set to danger (in most of the cases a red signal) the event is called a Signal Passed at Danger SPAD (Pasquini A, 2004). A review of the human factors and other key elements involved in the performance of the job will allow readers to develop an understanding of the role technology has played in safety standard improvements.

Human factors as mentioned and cognitive skills combined with work life balance and organisational culture will be explored within. Much research has been undertaken to establish best practice for driver training models and new safety devices so it is imperative that they are provided with the latest updates and resources to perform and drive in the safest manner possible (Banks, 2016).

Studies of driver performance and reaction to certain situations usually involve simulators as access to drivers can be difficult, this type of study has limitations compared to real world observations. Further examination will explore the difficulties in gathering this information, but hopefully gain a better understanding of the processes and schedule involved to get a better understanding of technology and innovation (Moloney, 2017). The research questions formulated are based on the writer's experience as a train driver, his observations of the improvements in the safety standards at Irish Rail.

"How have changes in technology improved the train driver's ability to perform their driving role safely?"

"Have the number of spads reported on Irish railways decreased over the last 20 years?"

"Has there been a notable decrease in accidents related to technological improvements?"

The question remains, have technological improvements and the introduction of new safety equipment helped to increase safety standards and reduce accidents or incidents. Further study of the elements that complement a driver while performing their role will help to evaluate this. Improvements in braking and safety control equipment have all contributed and benefited the driving role in making train travel a much safer experience.

Problem Statement.

The introduction of new safety technology has made train driving safer and has reduced the likelihood of an incident while travelling on the railway.

Chapter 1 – Introduction

Train travel is an important form of transport, it has evolved and transformed greatly over many years. The technological systems implemented have improved safety, reliability and efficiencies on the rail network. The safe operation and running of trains are paramount to mitigate the chance of accidents or signals passed at danger (SPADS). As a form of transport, train travel ranks as the second safest mode of transport (Stromberg, 2015). It's efficiency and reliability has ensured that trains are a popular choice for travel and also for heavy freight movement which also reduces the number of heavy vehicles on our roads.

This dissertation looks to assess has there been a reduction in the number of SPAD instances over the last 20 years both here in Ireland, the UK and the rest of the EU. Large scale capital investment is a necessity in the running of a railway, assets are usually high cost and maintenance of infrastructure is expensive with large associated operating costs (Eireann, 2019). There have been many incidents across Europe involving SPADS which sadly result in loss of life. These incidents also come with significant financial costs to train operating companies (TOC's), it is of great concern and any way to mitigate these incidents is welcomed.

The introduction of the European rail traffic management system (ERTMS) is to support interoperability on all European rail lines by 2028 to minimise the possibility of SPADS on their network (European, 2020). This material is worth reviewing and worthy of research into the field of railway safety to evaluate has there been an improvement in safety and a reduction in SPAD incidents. Previous studies of railway safety (European Union, 2018) confirm fatalities and serious incidents have reduced significantly between 2006 – 2016, see appendix

10. There were no explicit targets values derived for accident reductions, but where practically possible a measurable decrease was the aim for all TOC’s.

The building of railways in Ireland was largely done in the second half of the 19th century bringing ease of transport of both people and goods all over the country when there was much less motorised transport or haulage available (Admin, 2016). There has been much investment done in the latter part of the 20th century and presently the start of the 21st century to modernise and develop the strategic safety planning on the railway. Funds have come from many different programmes, including EU grants, European regional development plan and subsidies from the Irish government.

Implementation of these investments funded the railway safety programmes RSP (1999-2014). Currently Irish Rail are in the process and preparation for Dublin area rapid transport (DART) assessment works, this will provide guidance for passenger demand modelling and also for prioritisation of the DART Expansion Programme (NTA, 2016). Further funding has been allocated and is greater than the previous investment programme (Mykola, 2019).

The expansion of the DART has been approved with some €2bn investment under the national investment plan 2018-2027 (Ireland, 2018). This project will transform and connect the towns of Maynooth, Celbridge and Drogheda to the existing electrified network. The train protection system available presently on the DART line will now be expanded to include these commuter towns with this investment. Naturally safety is considered a primary concern for the travelling public in today’s environment.

TOC’s are charged with maintaining safety standards and implementing new technology and safety control equipment to compliment rail transport. Rail travel is generally considered safe and there is an expectation that TOC’s and regulatory bodies will make this their priority, previously though Irish Rail’s performance obligation in the NTA’s 2011 report did not mention safety as a preferred feature of the publication at that time (NTA, 2011). Looking forward customer safety issues are high on the agenda with a focus on maintaining the high standards achieved presently.

The scope of this dissertation includes research into the studies of human factors and cognitive skills in the driving role. An exploration of updated diesel multiple units braking systems and safety appliances developed especially for train running. It seeks to gain a greater understanding of the advances in operational performance. There is also an evaluation of driver behaviour while performing their role. Little study has been done in this area evaluating improvements in SPAD performance in recent years, one researcher (Moloney, 2017). touches on this subject in his in-depth works on simulator training for train drivers. There is a gap in the available research and this is why it was chosen as a means to understand and study improvements in rail safety technology & SPAD reductions.

The office of the Attorney General, HSE and HMRI deem certain rail activities as being safety critical. Train driving is also included in this determination. This means that, as part of the licensing arrangements, all staff involved in such work must be assessed regularly and certified as competent against risk-based competence standards (Moloney, 2017). There is also a review in the context of performance of European railway companies and how they regard the reductions in SPADS and an overall improvement in safety compliance.

The structure of this research incorporates the driving role, human factors, cognitive skills and technological advances in safe train operation. There is also a review of UK and EU rail safety and interoperability. An approach for understanding and exploration of other works in this field concerned with improvements in safety standards and reductions in SPAD incidents. Finally, there will be a thematic analysis of the data collected from the questionnaires. Coding and memoing will be utilised to organise the information into themes for analysis and findings.

Chapter 2 - Literature review.

1.1 Train driving role

A safe railway depends on strong operational decision making. As such the role of a train driver is to combine different types of static and dynamic information from the in-cab instruments and the external environment (Naghiyev, 2017). Using a combination of these pieces of information it is the function of a driver to complete a desired journey, to make certain designated stops at intermediate stations and also to drive in an efficient and safe manner. Drivers must always follow the rules and regulations as set out by the company. Examples of task analysis are shown in appendix 1. This list is not exhaustive as there are a number of other factors including cognitive elements and external environment awareness.

The experience and knowledge gained from driving many years on a certain route generally ensures safe travel where a driver can anticipate and plan ahead for unseen situations. Unfortunately, route knowledge and driver performance alone does not take into consideration factors such as loss of situational awareness, misread signals or fatigue which can lead to incidents on the rail.

1.2 Human Factors.

This area focuses on the fit between the driver their environment and equipment. The ergonomic study of the internal environment is needed to fully investigate challenges and difficulties. It allows research into human factors theory and methodology. Human factors play a significant role in advanced modern safety critical systems.

Automation of some processes to reduce human error is envisioned. Humans are centric for this conversion to modern new systems. Some of the priorities earmarked for review include, train cab design and the environment and Understanding driver route knowledge and driver experience, and the future role of the train driver (Wilson R. John, 2005).

As suggested by McLeod, more research into the psychology of the train driving task will identify risks involving SPAD incidents. Not much of the existing human factors research into train driving has tried to comprehend the mechanisms by which contextual and situational factors influence driver performance (McLeod Ronald W., 2005). While (Roth, 2009) research delves deeper into human factors study to understand the features of the driving role. His analysis of the situational model relating to planning and decision-making processes concludes that these result in definitive actions based on external environment conditions. The figure below illustrates a model of driver behaviour based on different elements.

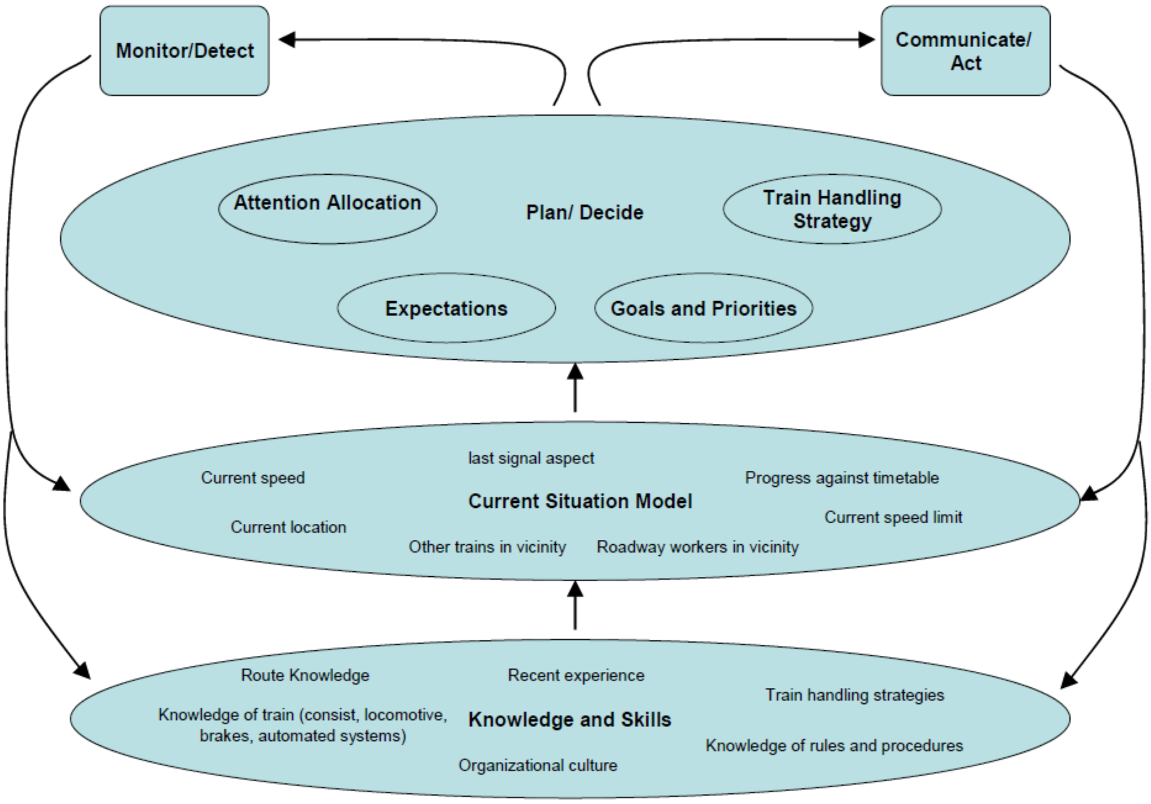


Fig 1.1 Simplified model of the knowledge, cognitive functions and processes that underlie locomotive engineer performance (Image from Roth et al 2009; p.22)

Most research on human factors has been concerned with SPADs, which is a signal passed at danger. These types of incidents have very serious consequences or can even be fatal as seen in many rail accidents, (Feehan, 2019). Human factors aside, there is always a risk that a driver will not react or misses a cue from the safety equipment which results in a SPAD that can have very serious consequences. This is discussed in greater detail in the SPAD section.

Railway operations are increasingly captured using digital technologies, such as on train-data-recorders, OTDR which record all control inputs by the train driver along with other metrics including speed, distance travelled, and GPS coordinates. Already widely used for fleet management and fault finding, the data may also have a potential human factors application in analysing and improving railway operations (Balfe, 2016). Data obtained from these downloads can be used in the application of new technology to ensure even safer rail transport in the future. Examples of the analysed data can be seen below. It shows corresponding data when a signal is degraded the braking system is applied and the speed is reduced.

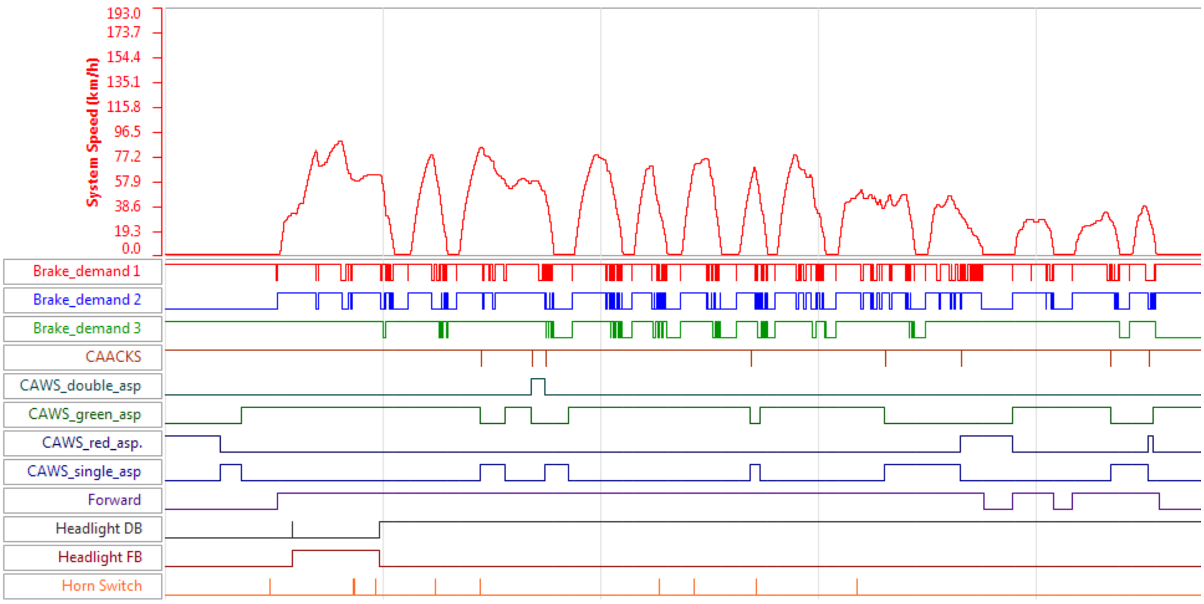


Fig 1.2, Model of OTDR analysis, image from (Balfe, 2016).

1.3 Observation.

The Evaluation of a driver's performance whether in cab or on a simulator enables DTEs to gauge their level of understanding of the safety equipment and capabilities. Practical application of these programmes to include, research on the effect on line speed on driver interaction with signals and signs, and the calculation of minimum reading times for signals (Wilson John R., 2005). These programmes have been of benefit for observation and recording of driver behaviour.

Not many studies have been carried out in the field of observation to monitor driver's behaviour in their working environment. One study by (Parkes, 2006) investigates the role and the complex relationships between factors approaching signals and other driving situations. He concludes that that signal aspect, preceding aspect, signal type and signal complexity are important factors, which affect the visual behaviour of train drivers.

1.4 Data recorders.

Train data recorders and speed checking are now common standards that are implemented by railway companies for post incident or accident investigation along with a live monitoring function. They provide DTEs with a means of observation if a driver has an incident of over speeding or shows any deficiencies in driver competence. Access to the OTDR can be gained remotely or locally by use of download peripherals. It is not permitted to allow a traction unit leave a depot where the equipment is not functional. The figure below is an example of an on board OTDR.

Fig 1.3 An example of an OTDR from 22000 class railcar. Image from (Tormey, 2021).

DTEs are required to also make use of handheld radar equipment to carry out speed checks periodically, usually once a month. This is to ensure compliance with speed limits or the introduction of an ESR. Usually these are introduced because of a broken rail or flooding on the line (5MPH).

1.5 Braking systems.

Braking system on rolling stock has improved greatly since the use of vacuum braked trains, this system was in use for many years before it's replacement with air brake trains. Introduced in the early 1970's the system was popular until the introduction of air braked units. The principle was simple, the vacuum brake system was controlled through a brake pipe connecting a brake valve in the driver's cab with braking equipment on every vehicle (Railway, 2019). An example of a vacuumed brake system is seen below.

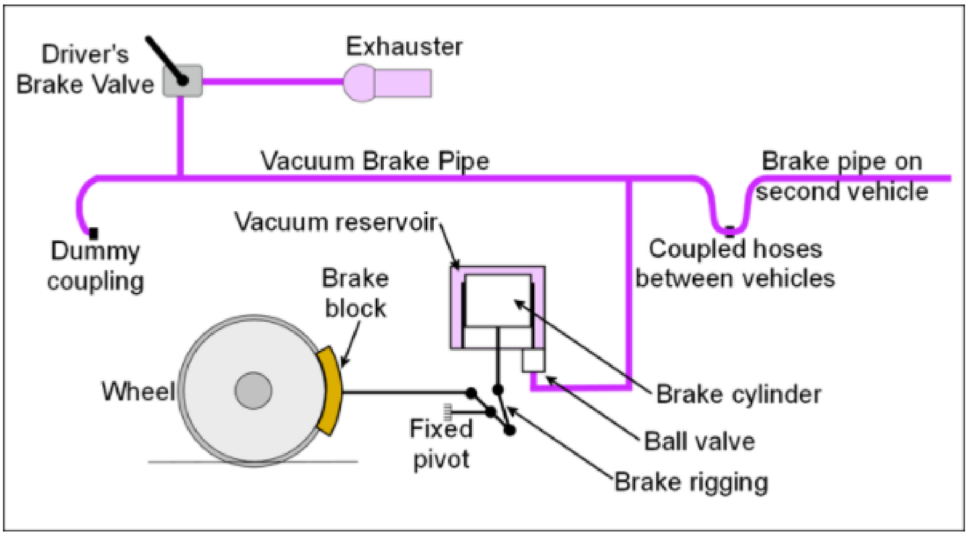


Fig 1.4 Model of a vacuum braked rail system (Image www.railway-technical.com).

Air brake trains are much more reliable and use a system of compressed air to apply the brake pads to the wheels of each axle. Pneumatic brakes also known as air brakes are more widely used now because of their reliability and control over the train. A hybrid braking system is presently operational on all rolling stock in Irish Rail, these have advanced performance characteristics compared to standard pneumatic brakes.

Presently modern technology has the ability to reduce the speed of a train when entering into such sections, thus reducing the likelihood of an accident (Di Claudio Mariano, 2014). Their studies into ATC and also ATO control and operation of autonomous rail vehicles have shown that full driverless systems do work and are a safe option. Train movement is controlled by a CBTC signalling and control system which uses radio transmission to keep in constant communication with each unit. There are also economic benefits associated with the move to full autonomy, increased reliability while also reducing operating costs. Shown below is a diagram of the operating system of the ATO.

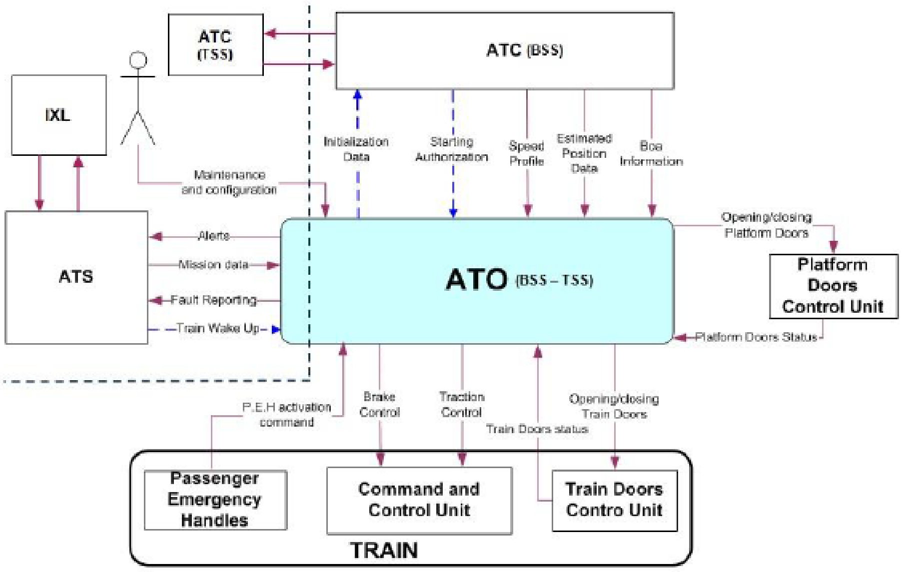


Figure 2. ATO Application Environment.

Fig 1.5 Model of the ATO system (Image from Di Claudio Marianio, 2014)

1.6 Simulators.

The use of simulators to train and observe drivers in emergency situations is of beneficial importance for rail operators. They can recreate any number of emergency situations without risks for passenger safety. As suggested by (Li, 2005) there are certain limitations in conducting simulated experiences in comparison to real world scenarios. Issues such as lineside speed limits or warning boards could be partially covered and screen glare or build-up of dirt can also detract from driving conditions. These are specific issues when driving in real world conditions which can negate the simulator experience.

(Groeger, 2001) performed a study measuring the comparative eye movement between in cab simulator instruments and the real-world environment. They found drivers spent more time focusing on the simulator assessment compared to actual driving of a train, this was attributed to the shallow environmental value of the simulation experience. (Wynne, 2019) also noted in their reviews of some 44 studies of simulators accuracy that, simulator studies required improvements, especially around the validation evidence associated with the simulator, the specific details of the simulated driving environment and the information from the statistical results. More recently (Moloney, 2017). has performed extensive and comprehensive research on the multiple benefits of simulator training for drivers. A cost benefit analysis was shown to be positive and the flexibility of the software are just some of the benefits achieved.

1.8 Mental workload.

Mental workload is often described as the interdependency of resources required for the task and the resources actually available to complete the task (Sheridan, 2008) this supports the fundamental findings of resource theory. The research of mental workload has been a significant part of human factors studies for many years.

The automation of trains and other forms of transport suggest that driver attention may just shift to tasks such as monitoring and thus not reducing the driver workload. As seen in the field of aviation, automation has shown some concerning results with pilots stating that even more monitoring increases their workload (Wickens, 2003), user expertise (Farrington-Draby Trudy, 2006). (Young, 2002) suggest a different perspective stems from Malleable attentional resource theory (MART), this suggests that there are different attentional pools that instead of having a fixed capacity, they are capable of changing and adjusting to suit the new tasks required. Thus, the performance decrease connected with the mental underload is explained by the insufficient attentional resources. The model shown below illustrates the responses to changes in demand.

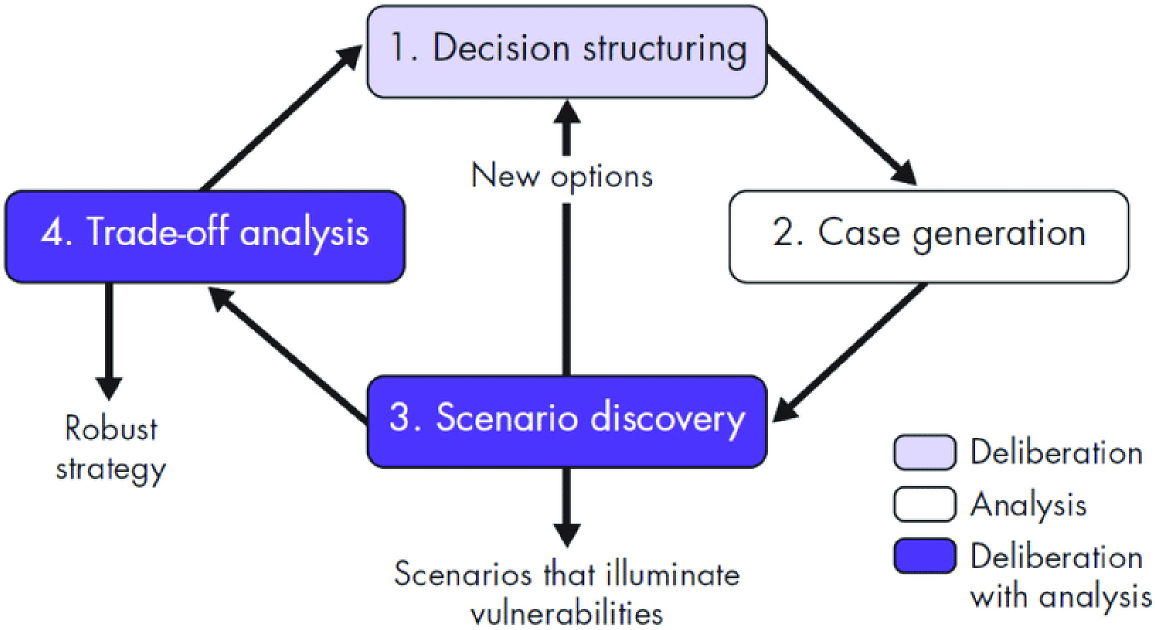


Figure 1.6 shows malleable attentional resource theory model, (from researchgate.net 2019)

Chapter 3 - Cognitive abilities

Cognitive skills.

The process of selection for the train driving role involves multiple stages, firstly two assessments comprised of psychometric and observational ability exams. There are also medicals and an interview stage, but most important is the cognitive skills assessment. This consists of hand eye coordination tests and responsiveness ability. Possessing a good cognitive capacity is essential as there are many distractions in a train cab. (Zoer, 2014) suggest that train drivers like pilots should possess a distinct set of psychological attributes to enable them to safely perform their role.

It is widespread practice within the military and civil aviation industries to assess the psychological suitability of candidates seeking employment as a pilot. Accordingly, our knowledge of the psychological attributes required by military and civilian pilots is well understood, as are the methods used to assess these attributes in prospective pilots (Wickens, 2003). These suitability traits are also required with trains carrying many hundreds of passengers at up to 100Mph, a driver’s error in judgement could be catastrophic if not fully focused and attentive to the situation at hand.

In different arenas multitasking is required to perform certain duties. Cognitive skill training is a possibility, these include skills to support contingency planning and attention sharing and task management along with prioritisation according to (Cheryl A. Bolstad, 2010). Some studies have shown that people with greater situational awareness also have a stronger ability in sharing attention for multitasking (Carretta, 1996). Many different factors combined help create a strong cognitive skillset.

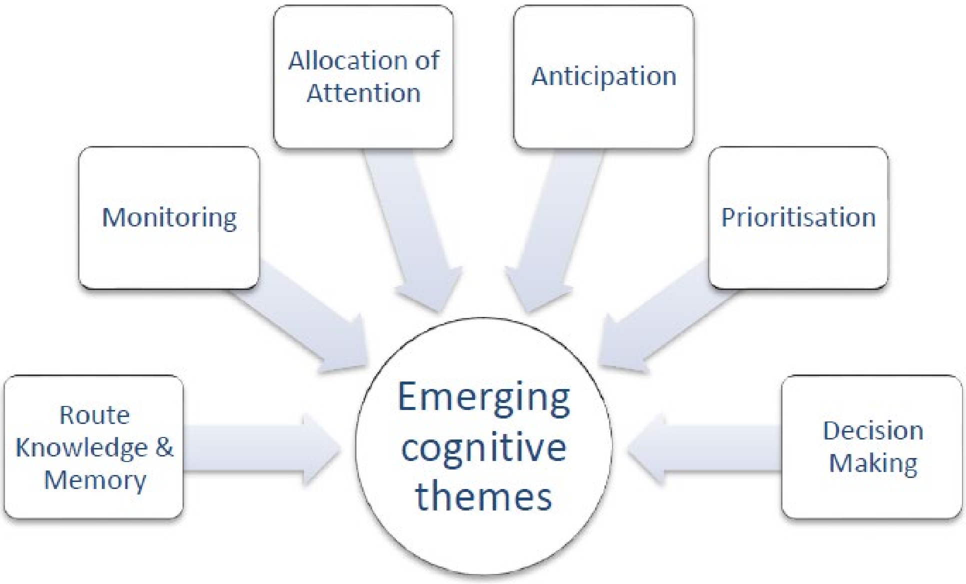


Figure 4.2: Emerging Themes of the Exploratory Study

Fig 1.7 different areas related to cognitive themes (Image from Naghiyev Arzoo, 2007).

2.1 Memory and route knowledge

Route knowledge over a certain portion of track is essential for safe driving, the driver must know precisely where each section begins and ends, where each signal is located and what route it applies too. They must know the location of level crossing and access gates to the rail line and also the mileposts of each of these and of course braking distances when approaching stations and any reduced speed limits applicable.

Driving during degraded conditions like fog or inclement weather has an impact also on how a driver should perform. Onboard the newest fleet of rolling stock there are satellite navigation systems which inform the driver of their location and the distance to the next station, this is especially helpful during periods of heavy fog or snow. In the model below the framework shows the process that drivers go through to perform their role. This model taken from (Monk Alice, 2019) uses a framework that creates a route story for the driver when learning new routes, it may also be used to assist in degraded driving conditions.

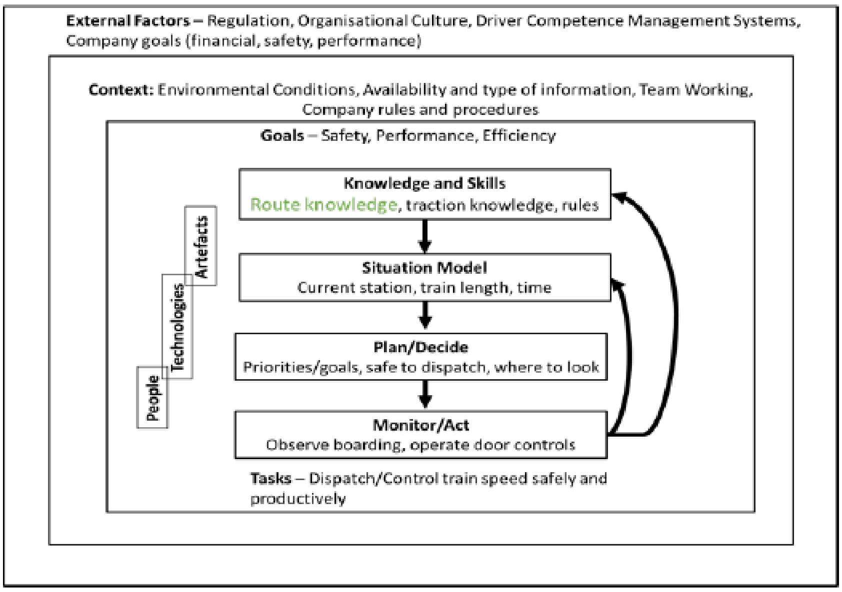


Figure 1: Route knowledge in the context of driver performance

Figure 1.8, Model of route learning approach based on route story (Image from Monk Alice, 2019).

The route story helps drivers build up valuable knowledge, as they gain more understanding and familiarity with the route, they gain an awareness of any issues in the sections and areas where increased attention or alertness is required. Generally, this is done over an 8-week period, this would be considered an appropriate time to learn a full intercity route, for example Dublin to Belfast or Dublin to Cork.

Drivers must retain large amounts of information, along with knowledge of the rule book and the professional driver's handbook it is expected that they are familiar with the traction unit they are driving. Each different Model of train has its own braking capabilities and power control units, the braking distance can vary greatly between some of the older fleet and the new intercity trains. These need to take this into account when driving in degraded conditions as it could have an adverse outcome if they are not practising the proper defensive driving techniques.

2.2 Monitoring

An awareness of the trains surroundings is imperative at all times, a need to monitor for any hazards or danger on or near the line is expected. Observation at gate crossings and level crossings along with approaches to platforms are also considered high-risk areas. Another essential role of the driving task is to consider movement authorities. Conventional and ATP drivers observe signals on the track, such as coloured lights and light emitting diodes, LED shunting discs.

Monitoring speed and controlling the movement of the train within the parameters laid out for the section is a primary function for the driver. The role of the driver is to observe any faults or warning messages on the in cab PIS system, this may involve some intervention or an action if warranted. The inclusion of automated subsystems now means that the role of the driver moves more towards supervisory control and there will be greater use of cognitive functions such as goal monitoring, exception handling and recognising anomalies onboard the train (Woods, 2010).

The introduction of closed circuit television, CCTV onboard has also complemented the driving role, the system can assist if there is a fire on board or there has been damage done to the train externally. A multitude of cameras watch and record all details of the journey which can be seen live or downloaded at a later time. In the case of fatalities which are not uncommon they will be used for evidence by the Gardai and later at the coroner's court. A snapshot of the CCTV screen is shown here.

Fig 1.81 shows an image of the CCTV monitoring system (Tormey 2021).

2.3 Decision making

Decision making and train control strategies are learned over a period of time by train drivers and used to make decisions regarding braking and accelerating. Knowledge built up from many years of driving the same routes help the driver make decisions about when to apply the brakes and at what position. Drivers need to plan a strategy when approaching downgraded signals or travelling in degraded weather conditions. There are many factors which impact this process including, train length, curvature of the line, gradients and level crossings or known areas of low rail adhesion. All of these will need to be taken into account to ensure safe and smooth braking and acceleration of the train, see appendix 4.

(Klein, 2008) explores the RPD model which describes how people can use their experiences in a collection of patterns. The patterns show the main casual factors operating in a situation. When a decision needs to be made the person can match the situation with a pattern they have learned. He argues that seeing these patterns regularly will encourage drivers to make better decisions. Driving has become more automated and decision making is becoming less of an issue with the automation of some on board technologies. Klein's RPD model is shown below, it reflects a mixture of analysis and use of intuition.

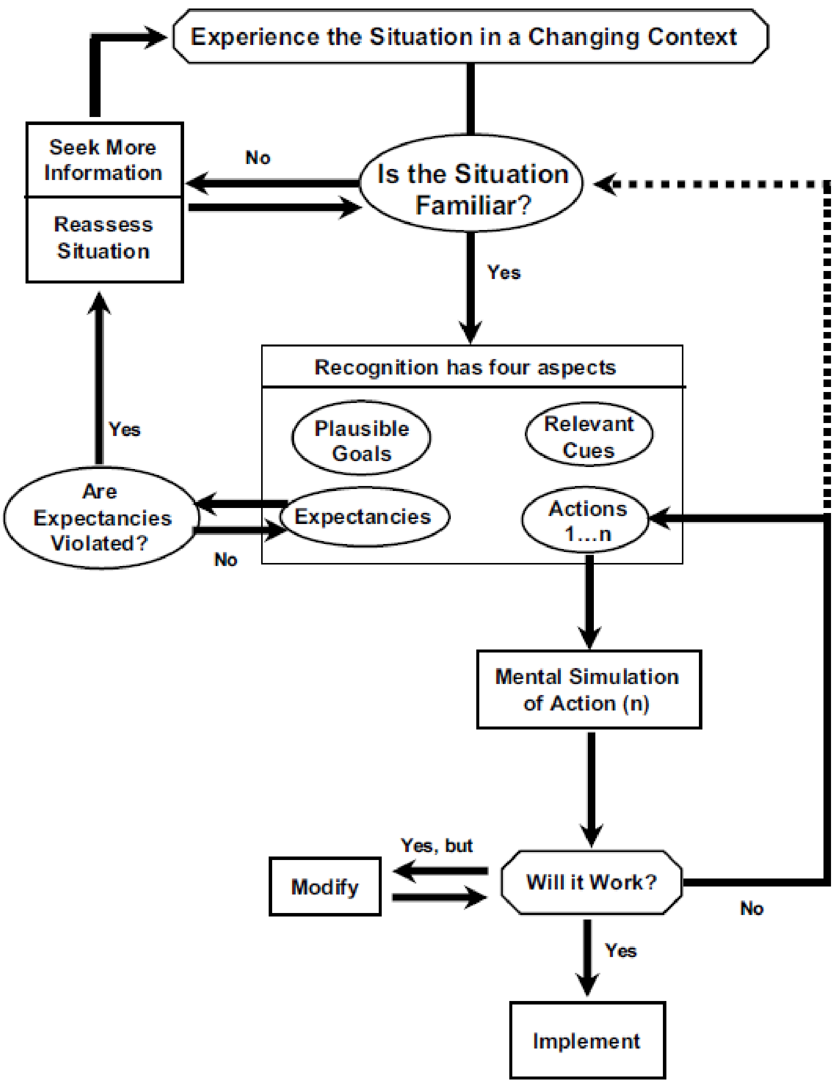
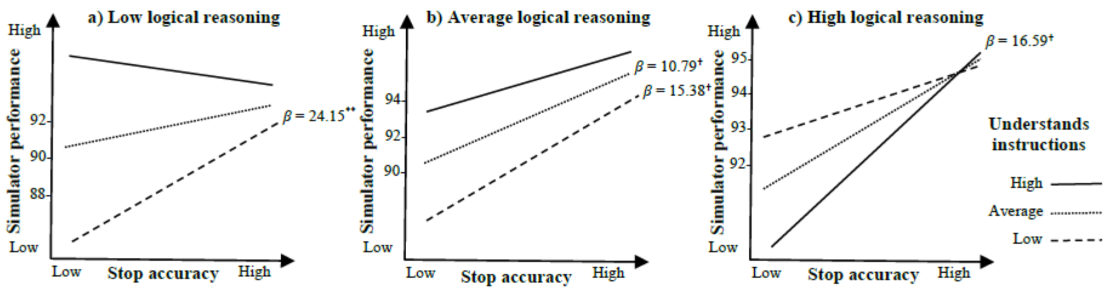


Figure 1.9 Model of recognition-primed decision making. (Decision making in action: Models and methods. G. A. Klein 2008.

2.4 Selection

It is widespread practice within the military and civil aviation industries to assess the psychological suitability of candidates seeking employment as a pilot (Wickens, 2003). After all, the safety of several hundred people, in the air and on the ground, might depend on the split-second decision that a commercial airline pilot makes in response to an out-of-course event or emergency.

A study carried out by (Hickey, 2017) on attention and cognitive flexibility concluded that there was a correlation between driving performance and attentional resource capacity. They contended that a major factor in driver performance is attributed to high cognitive flexibility and a driver's ability to disengage and switch attention rather than maintain their attention via working memory. (Moloney, 2017) analysis of driver cognitive attention shows that this is possible. Tests were carried out on simulators and the results are shown on a slope analysis below.



Note: only significant β reported. † $p < .10$; * $p < .05$; ** $p < .01$

Figure 2. Simple slope analysis.

Fig 2.0 Simple slope test model image from (Hickey R, Andrea 2017). (Hickey, 2017)

The technological advances of safety equipment and signalling systems mitigate the chances of rail accidents but driver performance in their environment is paramount for safe-working.

2.5 Situational awareness

Observing and maintaining situation awareness as a train driver in the driving environment is essential. This aligns with possession of strong route knowledge in their operating segment. Train drivers are required to have situational awareness by using information such as current location, current speed, the characteristics of the route landmarks, speed restrictions, the train timetable, characteristics of the train and tracks, location of other trains and track workers, potential sites of trespassers or hazards (Roth, 2009). Train drivers' route knowledge and experience allows them to anticipate what is going to happen next and this allows a driver to anticipate where they will have to direct their attention. Such situations, like what platform they will be directed onto and if they need to quickly direct their attention call for complete situational awareness (Tschirner, 2013).

2.6 Fatigue & Monotony.

Even with the advancement in technological equipment in the driving cab to alert the driver of danger, monotony and fatigue are always a factor in driving. There has been a large amount of research on train drivers. Fatigue has been shown to have adverse effects on mental and physical performance and can lead to a loss of efficiency, feelings of weariness and reluctance to mental or physical effort (Grandjean, 1997). Presently on Ireland's trains there are no systems to detect if a driver is beginning to lapse into a state of fatigue or sleepiness. On all trains there are safety control systems which must be acknowledged either by depressing a foot on a pedal or by use of hand on control lever to inform the safety apparatus that the driver is in full control of the train. Situations have arisen where the driver has failed to acknowledge the CAWS safety system, if not acknowledged within five seconds it will apply the emergency brakes.

There has been research and development of an intelligent fatigue system for train drivers which was carried out in India. The implementation of software and the combination of a webcam in the cab would set off audible alarms and also send a message to the controller. The proposed system of fatigue detection in train driver leads to new enhancement in technology and in the area of computers since developed system is the combination of hardware and software (Gulhane, 2014). Fatigue or burnout as described by (Fan Jialin, 2018).

Fatigue in the rail industry includes most of the features of occupational fatigue, and it is also subject to industry-specific factors. (Iridiastadi, 2020) outlines the findings of his study which generally showed that fatigue and sleepiness did characterize the job of train drivers, even for those who work morning shifts. The effects of fatigue on well-being and the fatigued population in the railway industry are still not clear. It is expected that a reduction of these situations will occur with more research and new systems implemented on rail transport.

2.7 Spads

Reducing the number of spads are a priority for railway operators, as discussed earlier the passing of a signal at danger, (a red aspect in the signal) can have catastrophic consequences. An in-cab appliance which if not acknowledged within five seconds will apply the brakes is called the continuous automatic warning system, CAWS. This safety device is fitted to all trains on the network, but not all sections of track have the system installed. The annual report by the (Commission, 2018) states that only 46% of the network is protected and that the equipment is outdated (Wall, 2016). An example of the CAWS system shown below. Irish Rails 2027 strategy aims to have all of its network covered with the new ATP control system by then (Strategy, 2021).

Fig 2.1, Image of CAWS system on Irish Rail rolling stock. (Tormey 2021).

In the UK the reduction in incidents has been significant in the last 20 years, the industry has reduced SPAD risk by more than 90 per cent (Global, 2019). The focus for transport companies now is on intense training and promoting awareness while also monitoring drivers. This has had a significant impact on reducing the number of these incidents, see appendix 3.

A number of rail accidents can be attributed to drivers failing to respect a red signal, Ladbroke Grove is an example of the outcome of such instances. On the 5th October 1999 two trains collided almost head on with the loss of 31 lives and over 430 passengers injured. The driver on one of the trains involved passed a red signal at danger and caused a major accident, the train was travelling too fast past the signal before the system could apply the emergency brake to prevent the impact with the crossing train (Lord Cullen, 2000).

Over the 2012-2016 period there have been on average, just under 1950 significant accidents each year on the EU railways. In these accidents, on average, just under 1050 persons are killed and 850 persons seriously injured each year (European Union, 2018). With millions of kilometres travelled every year on rail these figures represent an extremely low incident rate, see appendix 5. Below are statistics from the latest report from the EU agency for railways.

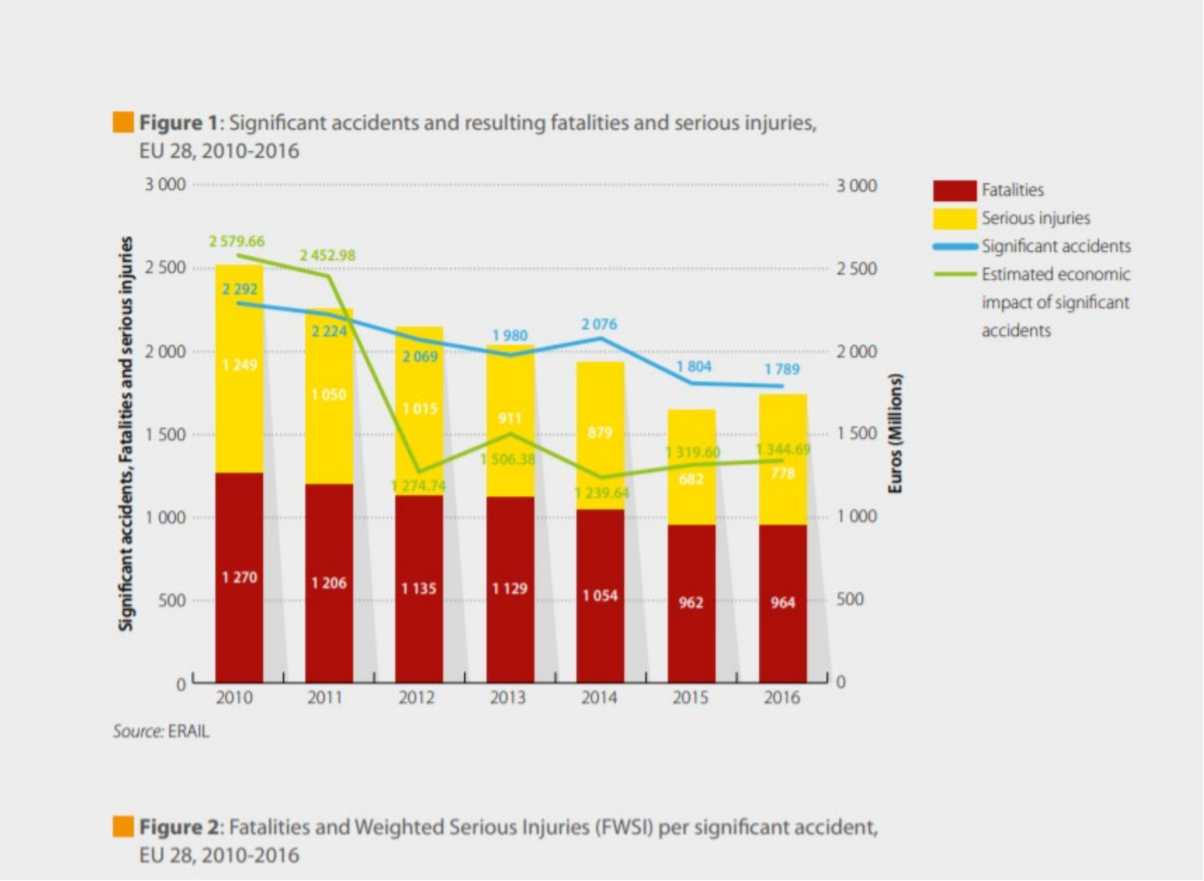


Fig 2.2 statistics from European Union agency for railways. (Image Europa.eu).

The implementation of the driver's reminder appliance DRA has had a very positive impact on start against signals SPAD's. These incidents accounted for almost 45% of all SPAD's in the period 2001-2016. The DRA is depressed when at a restrictive signal or at an intermediate station where the next signal is displaying a red signal. It is to remind the driver that they are driving on restrictive signals and to be attentive to their surroundings, when depressed the traction unit cannot take power which may prevent a driver mistakenly proceeding and causing a SASSPAD. An image of the DRA device is seen below.

Fig 2.3, Image of In-Cab DRA reminder device. (Tormey, 2021).

2.8 Incidents

Introduction.

Ireland's rail network has not recorded a major accident since the last incident and loss of life in August 1983. There has been some derailments and a bridge collapse recently but these incidents did not result in any loss of lives. The monitoring and investment in safety related aspects of the railway has increased significantly over the last 20 years, since 1999 almost €512m in expenditure has been allocated for safety management systems (Aecom, 2017).

Signal passed at danger.

The accident in Cherryville co. Kildare in 1983 happened because the driver of an approaching train hit the rear of a failed train in that section. He had passed a signal at danger without making contact with the controlling signalman, this was a requirement as set by the rule book at the time. The driver proceeded into the section with deadly consequences, 7 lives were lost and 55 passengers were injured (RAIU, 1983). The conclusion of the report found that the driver in rear should not have passed a red aspect without explicitly speaking to the controlling signalman and gaining his permission to proceed. He then should have proceeded cautiously at no more than 15MPH into the section, at the moment of impact the train speed was estimated at 34MPH. This accident could have been prevented if the safety control equipment was utilised correctly.

Speeding incident.

Abroad in Spain the Santiago de Compostela derailment occurred in 2013 when the driver of a highspeed train lost situational awareness and entered into a curve with a max speed of 80kph at almost twice this speed. 79 people lost their lives in this accident, the train in question was fitted with the ERTMS system to reduce the speed if a train was moving in excess of the speed limit. Unfortunately, at the location on this bend the track was shared with slower moving trains and the ERTMS safety system did not activate the braking system onboard the high- speed train (Vazquez-Jose-Iglesias, 2016). If activated the train would have been brought down to the permissible speed for that section of track. Shown below is the aftermath of speeding incident in Spain.

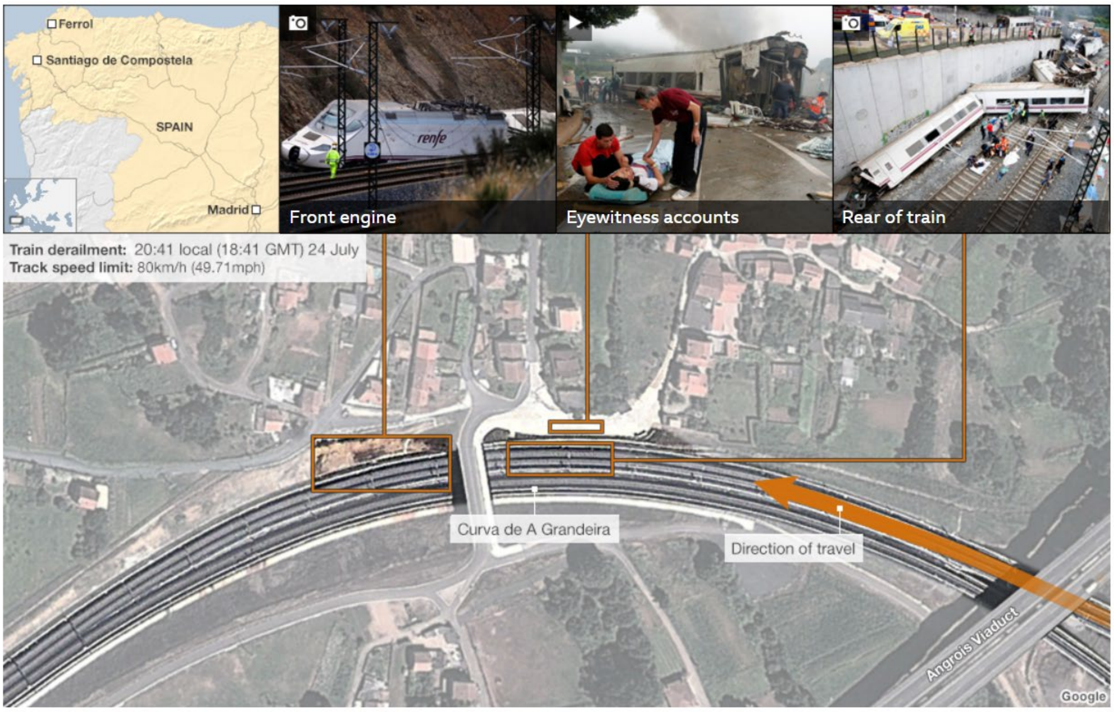


Fig 2.4 Curve at Santiago de Compostela (Image from BBC.com, 2017)

Mobile phone use.

Germany's latest train crash on February 9th 2016 was caused by the controlling signalman using his mobile phone while operating the signalling system on a high-speed single line (BBC, 2016). This resulted in the deaths of 10 passengers and over 100 passengers injured, an investigation concluded that the signalman was playing games on his mobile phone and records showed this corresponded with his working hours on a regular basis. Presently the use of mobile phones by any member of staff whose duties are safety related is prohibited, drivers are not permitted to use their phone 10 minutes before boarding any train. This is to prepare themselves mentally for their duty, anybody travelling in the cab in an official capacity must also turn off their phones. Distraction from mobile use has proven to be fatal in a number of accidents involving the railway (Lopez, 2010). Mobile phone usage causes distractions which lead a lower level of concentration within the driving cab while performing the driving role.

2.9 Artificial Intelligence.

Looking to the future, the aim for TOC's to reduce incidents and human error, artificial intelligence is seen as a possible solution for transport companies. The Spanish city of Malaga have already introduced a trial of fully autonomous public bus vehicles which uses AI to support decision making decisions on a city route (Europa, 2021). Recently the development of intelligent transport systems has received considerable attention, it's application in transport management systems are predicted to increase interconnectivity on AI transportation (Boukerche, 2020). According to the federal railroad administrators, the effect application of AI can produce fewer operational risks and enhance a safer rail transport system. (Baillargeon, 2020).

Government policies & regulatory bodies.

Legislation and procedure policy concerning the railway is the responsibility of the Irish Government who ensure Irish rail comply with EU regulations. In order to comply with new rules relating to an EU single railway area there have been new regulations introduced and which have been transposed into law in 2020. The 4th Railway Package is a set of 6 legislative texts designed to complete the single market for Rail services (European, 2018) (Single European Railway Area).

The European union agency ensures compliance for all aspects of the 4th railway package throughout the EU. Regulatory bodies like the CRR ensure no one is allowed to operate a railway or manage railway infrastructure in the State unless they have obtained the appropriate safety certificate or authorisation from the CRR as the National safety Authority (Commission, 2018).

Conclusions.

This research has concluded that incidents of SPADs on Irish railways and the EU have decreased significantly over the last 20 years. Studies of analysis conducted by TOC's have shown reductions in the number of incidents which can be attributed to new training techniques, as seen in simulator studies (Moloney, 2017). and implementation of improved safety equipment CAWS on Irish Rail's rolling stock and the ERTMS (Naghiyev, 2017) system in the UK and Europe. Technological advances in braking systems (Di Claudio Mariano, 2014) and DRA reminder appliances have all contributed to safety standard enhancement in this well-controlled working environment.

Information through extensive studies from the EU agency for the years 2010-2015 have shown passenger risks or fatalities have decreased, see Appendix 8. Research from Irish Rail and UK TOC's have also shown significant reductions in drivers passing signals at danger. The introduction of the DRA appliance in driving cabs has had a very positive impact in reducing the instances of SASSPADS, information regarding these reductions is shown below in appendix 9. This paper describes the methods used to research spad reductions, improve safety standards and understand driver performance in their roles.

Using qualitative data for the research was invaluable in researching potential human factors issues, information collected in the course of the study was relatable to almost all drivers interviewed. (Zoer, 2014) suggested that train drivers like pilots should possess a distinct set of psychological attributes to enable them to safely perform their role, a review of these cognitive skills gives a richer understanding of the complex factors in human performance.

Technological updates and improvements to equipment in the driving cab have been synonymous with a much-improved safety record, see (appendix 3). The introduction of the CAWS system to aid drivers with anticipation of lineside signals and also the introduction of DRA technology which has seen a decrease of SASSPADS since its launch. These appliances compliment the driver in maintaining the high standard of driving seen presently in Irish Rail and the other safety systems in use across the EU, namely the ERTMS system.

As evidenced by (Moloney, 2017) the advancement of simulator training has evolved over time to provide a much greater training experience for the driver. The role has become increasingly cognitive and this required a more suitable training function. This coupled with multiple scenario presentations has ensured a safer model for the training environment.

Greater knowledge and investment in human factors studies will have a positive effect in implementation, design and operation of research programmes. This has been echoed by the implementation of new safety management systems across Europe, these measures are provided to reduce human error. Specific new ergonomic design will enhance the driving role to facilitate hybrid control.

This researcher was fortunate to have some access to drivers and DTE's alike which has helped immensely in the production of his work. Gathering views and specific information steered the research into an overall exploratory approach of data analysis and provided an important understanding of the safety culture within the railway. I am extremely grateful for all the participation and support.

Future study into the risks associated with SPAD's and safety development may include, the comprehensive strategy in the safety risk model in progress with Sotera. The Risk Model provides risk estimates for passengers, staff, members of the public and trespassers. The Risk Model is predictive; it does not rely on past accident data to estimate risk, but investigates a wide range of precursor events and explores how each of these may escalate to become an accident using fault and event tree analysis (Chapman, 2019). TOC's ambitions of maintaining undesired accidents are the ultimate goal.

The Research Methodology

Research Methodology.

The choice of qualitative data for research.

The inspiration for this research was derived from personal experience, the study was best suited to a qualitative method for researching my topic. As an ex-driver I had some knowledge and background information that I could use and develop in this piece of work. There was also a lack of access to relevant persons who could participate and assist me throughout the process, under normal circumstances this might not have been an issue. The methodology used herein will be qualitative in nature, using a questionnaire.

The subjects are all experienced train driving staff and also DTEs of the driving grade at Irish Rail. Participants between them all have over 240 years driving experience so the information and thoughts from each and every person was invaluable to me. Given the situation we find ourselves in with the pandemic and the tight restrictions currently in place I was extremely lucky to be able to have access for the questionnaires with my subjects over the month of March 2021.

The type of information I needed was best sourced with questionnaires from subjects with vast amounts of experience and background knowledge of the railway industry. As noted by (Adams, 2008) that a questionnaire is a tool and as such it must be usable so that the reader can easily understand, interpret and complete it. This in turn will increase the accuracy of responses. A quantitative approach would not have been suitable for this process.

Some tables and statistics are used within this work but these only serve to compliment the feedback from participants. The qualitative approach will give feedback about perspective, meaning and driver experience which cannot be shown in the quantitative method, as seen in previous studies conducted with questionnaires. (Pasquini A, 2004), conducted an investigation into the analysis of SPADS. (RSSB, 2012), carried out a risk assessment of the dangers of mobile phone use in the cab. (Giesemann, 2013), conducted research into the automation effects in train driving.

The choice of qualitative data collection for this study was due to the nature of the research, to ensure a thorough analysis of drivers and DTE's experience in their roles. Quantitative research for a number of reasons would not suit this study because:

(a). It is limited in its goal of statistical relationships.

(b). The positivism research disregards common meanings of social phenomenon.

(c). It measures variables at a specific moment of time.

(d). There is no availability to specific feedback.

Qualitative work requires reflection on the part of researchers, both before and during the research process, as a way of providing context and understanding for readers. When being reflexive, researchers should not try to simply ignore or avoid their own biases, instead reflexivity requires researchers to reflect upon and clearly articulate their position and subjectivities (Sutton, 2015).

The value of this process was important for me to try and understand the information provided by the responders. I wanted to gain an insight and have a deeper understanding of their reasoning and feedback given. The information would give me an opportunity to delve deeper into their answers on the questionnaires to assist in forming an analysis of the data. Memoing and coding were used with the feedback from each of the questionnaires to assist with highlighting common themes. This enhanced the approach of the qualitative method while reviewing patterns in the participants data. The most beneficial use of memoing is to assist with decision making and act as a guide through the many different stages to show how decisions were arrived at before completion of the study.

Research philosophy as described by (Saunders, 2019) is concerned with the development of knowledge in a chosen field, refers to the system of beliefs and assumptions gathered in the particular area we choose to study. This research methodology will focus on an ontology approach to the data, using an interpretivist view of the elements. The research strategy involves questionnaires to understand the data in a qualitative method. Primary and secondary data sources collected will play a role in the analysis.

(Saunders, 2019) developed a research model in 2007 to give researchers a tool to better understand the different elements of research when conducting data analysis. This illustration is shown below.

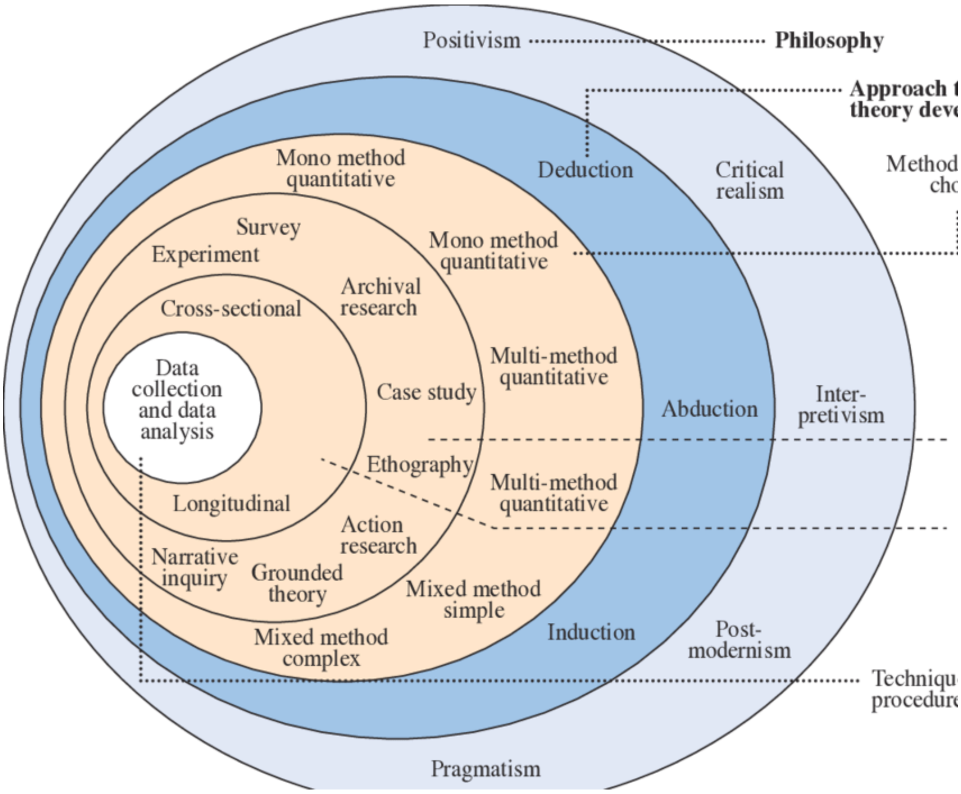


Fig 2.5 Saunders research onion (Image Researchgate.net 2018).

Primary research

This primary research was carried out to gather information first hand from experienced drivers and DTE's at Connolly station within Irish Rail in the form of a questionnaire. A body of work by (Cooper, 2012) has encapsulated the theoretic orientations and importance of primary research. Analysing their responses and data has given much insight into how they believe safety has improved on the railway. They were selected because of their experiences and knowledge of the rail industry in the previous 20 years or so. There is a trust built up over many years working alongside my colleagues which enabled them to be at ease while I elicited information to ensure genuine and honest responses.

Average length of service of train drivers.

				Average length of service as a train driver		
Years		**5-10Yrs**	**10-15Yrs**	**16-20Yrs**	**20-25Yrs**	**25+Yrs**
Train drivers		**3**	**9**	**4**	**2**	**1**

Table 1, Length of driver's service.

Average length of service as DTE's

				Average length of service as a DTE		
Years		**5-10Yrs**	**10-15Yrs**	**16-20Yrs**	**20-25Yrs**	**25+Yrs**
DTE's		**0**	**2**	**2**	**1**	**0**

Table 2, length of DTE's service.

The decision to use questionnaires was centred around a number of studies researched in the course of this work. The presence of an interviewer may not elicit a valid response because of a number of reasons. Familiarity with the interviewer or a reluctance to say something that may be deemed inappropriate or what the interviewer may want to hear can affect the responses. Some advantages of a questionnaire are the anomality of the participant, they feel more relaxed answering in their own time and then may be more willing to expand or express controversial opinions.

In relation to the questions being asked, they centred around the driver's experience on the job and how they perceived the improvements in the train cab environment and workplace. Questioning and the order they appeared was important as I wanted their responses to be natural in how they considered answering each one. Careful selection and testing of the questionnaire was implemented with a colleague to make changes and to rephrase some questions for a better understanding.

Secondary research

The use of secondary research involves interpreting or re-analysing previously collected data, these data include material such as semi-structured interviews, responses to open-ended questions in questionnaires (Heaton, 2008). In producing this work many articles and research papers gave great insight into the field of data analysis of railway operations. They were invaluable while working on this project, and are detailed in the literature review.

Unfortunately, there wasn't much research into the field of SPAD reductions in Ireland. (Moloney, 2017) and (Monk Alice, 2019) both conducted extensive research in their respective fields but they did not serve my needs for this particular study. I made use of other sources of information, the practice of promoting and sharing of secondary data analysis allows for a transfer of knowledge between many different stakeholders which is recognised by researchers (Ruggiano, 2019). Below is a table with primary and secondary research definitions.

Comparison basis	PRIMARY RESEARCH	SECONDARY RESEARCH
Definition	Involves collecting factual, first-hand data at the time of the research project	Involves the use of data that was collected by somebody else in the past
Type of data	Real-time data	Past data
Conducted by	The researcher himself/herself	Somebody else
Needs	Addresses specific needs of the researcher	May not directly address the researcher's needs
Involvement	Researcher is very involved	Researcher is less involved
Completion time	Long	Short
Cost	High	Low

Table 3, difference between primary and secondary research. Source (www.oxbridgeessays.com).

This is a brief introduction to train driving, the functions and role within the company.

Train operation and technical specification for interoperability and the minimum standards for drivers consist of, the European Directive on train driver licensing. Said (Article 10) requires each member state to set a minimum age for train drivers of not less than 20 years for international services or 18 years for domestic services. The minimum age of 21 years for IR mainline network drivers (domestic services) is based on an assessment of risks as well as legal opinion, and perpetuates the existing requirement (RSSB, 2020).

Many of the drivers began their career with Irish Rail in a different capacity from where they work now. Some started working either on platforms learning the workings of the railway internally, others may have worked on level crossings with not much interaction with rail staff. Moving through their career path to become drivers meant taking many safety related courses and rules exams.

These bi-yearly rules exams ensured compliance with the rules set out for all grades within the rail network. Coupled with the rule's element the role of a driver is to ensure safe and efficient driving whether transporting freight or passengers. An understanding of the standards laid out and how drivers interpret the rules applicable to them driving is imperative.

Driver's questionnaire results.

1. What are the most important changes in technology that affect your daily driving?

   All of the drivers gave a resounding approval of the DRA appliance installed in the cab this was the dominant piece of technology the drivers agreed upon. Nineteen of them all concurred that this device has had a tremendous effect on how they behave at degraded signals or locations where there may be a distraction likely to cause a lack of concentration.

   Drivers also mentioned that CCTV on board the trains have proved to be very effective especially at peak times. Some train stations built on a curve will have limited vision for the driver, two city centre stations Tara street and Connolly station both have this issue. Some of the longer trains are approx. 120 metres long so this technology has been much welcomed.

   Fourteen of the drivers discussed the importance of the CAWS system, this is to alert them of displaying aspect of the next signal. In periods of degraded driving conditions and inclement weather the CAWS is a complementary tool for the driver.

   Sixteen of the drivers have mentioned that the newest trains in the fleet have an improved braking system which gives confidence in the driving role in periods of wet weather and the low rail adhesion season. This is when leaves fall on the tracks (Sept-Nov) usually creating slip slide occurrences which may lead to overruns at a station or signals.

There were a small number of drivers, six who think the new LED aspects on signals have made it much easier to identify signals from a distance including inclement weather or fog.

2. How would you describe the introduction of safety related equipment on board trains?

Fourteen of the drivers questioned felt that in terms of safety, they obviously have huge benefits to the company, passengers and drivers. However, for drivers it may be felt that they detract from the skill of driving as most new safety related equipment takes a lot of the driving away from the driver.

Four others disagreed with them and think that it can only benefit a driver to have more safety related equipment to assist the role. One person thinks the company are not doing enough and are quite slow in upgrading new technology.

3. Would you say driving has become heavily reliant on computer aided support systems and why?

Almost all of the drivers, seventeen agree that presently with modern technology the railway has been slow to invest and reluctant to rely on computer systems. Driver's still having to carry a heavy driver's bag full of safety equipment would be an example of how slow the railway is to rely on computer systems. Two drivers mentioned that a portable tablet could contain all the books and manuals that are required presently.

One person mentioned that we are well behind our European counterparts in relation to the introduction of hybrid trains and the safety functions in use there.

From a driving perspective most agree that it is still the driver who is control of the train using knowledge and experience gained from many years working a certain route that is the core function. Thus, from a monitoring perspective there are many computer aided tools on board which record in real time every portion of a journey and action taken by a driver.

Looking towards the future the introduction of the new hybrid fleet will have many more computer-based systems to compliment the driving grade.

4. **As a driver, how would you describe the safety standards that apply to the driving grade?**

There was a mixture of responses that drivers thought were important ranging from,

(a). The standards are sufficient in maintaining the high level of compliance.

(b). Some staff feel they are not consistently applied to all incidents.

(c). There is a sentiment that they are used to punish rather than assist the driver.

(d). One respondent thinks they are too stringent, to the point they place additional pressure on a driver with previous incidents on their record.

5. **Working as an DTE how would you describe the training and monitoring of drivers from trainee to full driving position?**

The DTE's regards their role as that of a teacher. The training of drivers is undertaken to a very high standard with rigorous checks and monitoring not only of driving skills but also the critical safety rules that apply to a driver.

One said it is very clearly defined what is required from the standards provided and also from the trackers that are in place to ensure trainee drivers are reaching the level required. What he feels is lacking is a proper selection process for the choice of mentor drivers. Drivers should be selected to mentor based on their desire to do the job properly. It should not be a free for all as some drivers may just do it for the monetary gain as it is presently or how good it might look on their CV.

Two others agreed that the monitoring of trainees is sufficient for the important safety related role they perform, the monitoring of drivers can seem a little overbearing at times, but they fully understand why they are necessary.

6. Has fatigue ever had an impact on your driving capabilities at any time?

Twelve drivers responded that they have never suffered from fatigue in the workplace citing reasons from the professional driver's handbook. There are 12 hours rest allowed for your next shift and as a professional driver it's your responsibility to get sufficient rest and recuperation. The shifts are designed for a better work life balance, allowing for shift work.

Some six drivers replied that they have felt fatigued at some stage in their careers. They pointed to very early morning starts one week then working on a late turn the week after. Having a balance between family life and the daily requirements with young children played a role in this. One driver said I would be dishonest if I said getting up at 2.30am in the morning and then driving to work to start a 3.30am shift and fatigue would not have an effect on your train driving duties.

One respondent admitted that they had actually lost concentration and became disorientated because of tiredness attributed to night work.

7. Does your training provide for failure of any safety related equipment to allow you to complete a journey?

This was a very positive yes from all staff, the rigorous training programme along with the 250 hours out road learning and 40 hours night driving ensured drivers had plenty of experience when dealing with a failure. If a fault cannot be solved by the driver there is direct radio contact with the maintenance depot who will help and also might me able to see what the issue is on their computer.

Staff feel confident that fault finding training is quite good and will generally facilitate the train making it back to the depot for repairs. In certain circumstances this is not always possible so another train may be sent out to assist the failure. There are certain rules and regulations regarding how and when this is permitted.

A couple of drivers pointed out that a yearly course keeps you up to date with safety features and also if any questions needed to be answered there is always contact available once it's not an emergency situation obviously.

8. Are there any limitations or barriers when bringing a safety issue to your manager?

There were differing opinions on this question, some of the drivers had negative feedback regarding how issues were received. But mostly, fifteen drivers had no problem and benefited from positive feedback from their managers. Listed below are the responses.

(a). A driver may be hesitant in case they may have accidently done something wrong, thus implicating themselves.

(b). Don't want to inconvenience their manager about a perceived small problem, or seen as a trouble maker for raising a legitimate concern.

(c). Excellent feedback when they did approach their manager as it may prevent it happening to another driver or colleague.

(d). One brought an issue to a manager but felt specific rules were ignored to resolve a situation.

(e). The majority felt comfortable and at ease with no obvious barriers in place when taking an issue to a manager. Two of the drivers did mention that doesn't always result in any action been taken.

9. Has there been a time where you may have lost situational awareness and the technology installed has helped you resolve the issue?

Sixteen drivers answered no to this question, they said full focus on their driving role ensures that this never happens. Situational awareness is extremely important while driving in poor weather conditions or in darkness driving. One driver reported that he may have lost situational awareness before but used their own route knowledge and risk triggered commentary to bring me back to the present.

The three other drivers explained that this was uncommon but has happened and the safety equipment in the cab, the CAWS was able to determine what aspect the previous signal was displaying. Another spoke of the new MMI screens which have a global positioning system installed, these will display the distance to the next station and roughly where the train is in any section. This was most defiantly of benefit as they were driving in thick fog at the time.

10. Would you say there is a positive safety culture reinforced by the safety management system?

Much positive feedback was recorded for this question, drivers felt that safety was always a priority and it is generally accepted that there cannot be any exceptions for it. The railway management system demonstrates a high level of safety and this feeds down throughout the company emphasising the importance of safety to all employees.

Two of the staff had a small problem with how a concern they had was handled, this can differ depending on what the issue is and who you bring the issue to. They said some managers are much more approachable and will at the very least make enquiries. Others can be quite dismissive of your concerns if they do not feel they are important enough to justify doing something about this. It could be seen as a funding issue in relation to inaction on safety concerns.

The majority of drivers did feel that safety related problems or issues are prioritised and acted upon in a timely manner.

11. Do you think the extensive training and job design has enabled you to adhere to the professional standards?

Eighteen drivers agreed with this, they responded with the professionalism standards expected have been matched from the training from the company. The training and learning allow you to work well within the standards, however there is a big amount of personal responsibility in ensuring that you apply this training and learning in a proactive way. It's very easy to become complacent and you must motivate yourself to keep your standards high. It can easily slip, and the risk is the only time that gets noticed is when you have an operational incident.

Each year drivers have to attend and participate in safety courses and receive education. They regularly get new manuals and updated information on improving standards and how to adhere to them. We are constantly reminded of our job importance and helped in numerous ways on how to improve and keep up the excellent standards.

One person was not of that opinion, they believed that experience was more important than any new training or modules they may have been required to attend. Overall, there was great satisfaction in how the company performed in this area.

12. How confident are you that the high standards achieved in safety within Irish Rail will be sustained into the future?

All drivers have acknowledged that the company will continue to maintain it’s high standards achieved in safety related matters. They remained confident safety standards will be maintained into the future. The consistent efforts to evaluate the standards on a daily basis will ensure that happens. Ever changing technology and significant resource allocation are cited as some of the reasons why.

There is a view that year on year there's been an increase in emphasis with regard to safety practices & procedures in all grades. A driver remarked “These standards are now part and parcel of daily activities within Irish Rail and are adhered to as normal practice. The railway industry must sustain these standards as it is a core principle of their business model”.

Two of the drivers said they were slightly concerned about drivers being hired from outside the company, their reasoning was they have no background experience of the railway and do not understand it workings.

13. How would you view your cognitive skills in any aspect of train driving?

Drivers are more aware of the cognitive factors they experience while carrying out their roles. Cognitive skills are very important in the role of a train driver, at all times you need to be aware of cognitive underload and overload. Underload has been on the increase during the Covid pandemic with fewer trains and passenger levels at an extremely low figure. Cognitive themes are now an issue commonly reviewed within Irish Rail. Some of the responses are detailed below.

(a). Drivers feel that their cognitive skills have not changed because the nature of the role requires them to be alert and responsive constantly.

(b). Some think that cognitive skills are not as important as real experience learned from twenty years or more of driving.

(c). Two believed that there is a dynamic risk associated with the role and each driver should be able to manage that risk.

(d). This was recorded by six of the driving staff, the most important cognitive skill is maintaining concentration for a long period, not becoming complacent when operating the train.

14. In the DTE grade how important is it to keep up with the latest standards introduced by the commission for railway regulation?

All five DTE's responded with similar thoughts on how It is of great importance to keep up with the latest safety standards so that you can adequately brief drivers on these standards. Critically important, not only for a driver but also because a DTE is normally the first port of call for drivers in almost all aspects of safety related queries. Any updates when it applies to standards and also for not giving out false information which could lead to critical mistakes or errors

Chapter 5. Data Results

Data collection

Qualitative data collection is usually carried out in the form of a focus group or in an interview setting, it can also take the form of a questionnaire (York, 2018). It is then the decision of the researcher to select the most appropriate method for data analysis after assessment of the pros and cons. In the current restrictions that we are faced with, interviews have become an almost near impossibility.

The use of a questionnaire to gather this information enables analysis of open-ended questions with qualitative methods. Some advantages are the faster timeframe to collect data and lower costs compared to other collection methods, also it puts less pressure on respondents when answering questions. Using open ended questions for this study hopefully will produce unexpected results and valuable information to analyse.

Anonymity for a participant would reinforce a sense of neutrality and privacy when disclosing information when not in the presence of an interviewer (Richman, 1999). This alone makes for interesting and honest feedback for the research. Twenty-two sets of questions were emailed to to drivers along with five more to the DTE's with their permission. One driver decided to not participate in the study for personal reasons. Another two did not return their answers after a couple of requests so these were not taken into account. In total 24 members of the driving staff participated which accounts for slightly more than 26% of all drivers in Connolly station.

The researcher would once again like to thank everyone who participated in the test pilot questions and this the final questionnaire outcome.

Thematic Analysis of qualitative data

Thematic analysis is used as a method of examining patterns with a set of research data, it is essential for credible qualitative research. The (Braun, 2006) framework can be applied in a systematic manner to explain the process of analysis within a context of learning research. It is a helpful tool that is not constrained by limitations when searching for patterns in respondent's data. Careful analysis and discovering themes that already exist within the questionnaire data are necessary to confirm evidence of pre-existing themes.

Using the method of capturing a recurring pattern in the data collected has enabled the creation of tables with sub themes for this section of work. All of the relevant information has been extracted for collation. The questionnaire data can now be compared for themes from the original data set. This has been fully analysed and not just described from data collection. It provides a good fit between the analytic narrative and gives explanatory meaning to the analysis of the position.

To fully understand the flexibility of thematic analysis, (Terry, 2017) evaluates how thematic analysis can be conducted within various ontological frameworks. These will relate to epistemological approaches to data, this does not mean that TA is atheoretical TA needs a theoretical underpinning, and researchers need to be clear about what this is. Considering these approaches, the language and concepts are consistent with the analysis.

Table 4. Emerging themes and sub themes created from questionnaires.

	Main theme	Sub themes
Theme 1	Acceptance of new technology	a. Acceptance b. Risk perception c. Trust d. Future issues
Theme 2	Mental workload	a. Overload b. Underload c. Limitations
Theme 3	Route knowledge/experience	a. Lack of experience b. Situational awareness c. Memory retention d. Familiarity e. Loss of route knowledge
Theme 4	Cognitive skills	a. Driver selection b. Attentional resources c. Cognitive flexibility
Theme 5	Implementation of safety related equipment	a. Benefits b. Detract from driving role c. Distrust
Theme 6	Safety standards	a. Positivity towards standards b. Acceptance of industry needs c. Lack of familiarisation

The thematic analysis data recorded is displayed in the table 4 above and the associated sub theme tables below. These give a breakdown of the respondent's responses from their questionnaires. The first theme, acceptance of new technology is presented and discussed within.

Table 5. Acceptance of new technology

Sub Themes	*Examples*	*Description*
1. *Acceptance*	Drivers believe that new technology has had an impact on safer driving. The inclusion of safety equipment helps focus on the primary driving task. One person commented that the introduction of technology was too slow in coming into the industry.	Staff described the introduction as a welcome tool. It is seen as an aid to the driving role which also complemented their function. Mostly accepted after initial scepticism because it was seen as a lack of faith in their driving abilities or decision making.
2. *Risk perception*	It is intended to assist the driver, but some have said there is a distraction element associated with the equipment. Spending more time looking at the MMI screen leads to a switch of concentration to outside elements.	The introduction of the DRA device has by four drivers accounts saved them from a possible SPAD incident. Many others believe that too much emphasis is placed on internal MMI system, leading to enhanced risks in external environment hazards.
3. *Trust*	There was a strong belief in the technology as a tool to enhance the driving role. With incidents of loss of situational awareness, the SAT NAV gave a positive reassurance and information in real time to assist the driver. Two drivers didn't place much trust in the system and preferred to drive unaided.	There was an incident when the technology failed to perform as intended, this had a major influence on driver's belief in the system. Suspicion about its integrity remained until downloads and an investigation revealed an error by a member of staff. Generally, a positive response to its abilities.
4. *Future issues*	The future of new technology has been welcomed by most of the driving staff, they are geared towards keeping a driver focused and alert. Arriving not long from now the new CAWS hybrid system will benefit and support safer driving.	The introduction of CCTV on all aspects of the train has proved to be very effective in stations with curvatures on the line. New hybrid braking systems are also hailed as highly effective in inclement driving conditions.

The second theme, mental workload is associated with driver's concentration and attention. Examples and the descriptions are below in table 6.

Table 6. Mental workload.

Sub Themes	Examples	Description
1. Overload	Drivers have expressed how the remote monitoring of live journeys has an impact on how they drive. They feel instances of over speeding or failure to use the horn or head lights will be noticed and brought to their attention more frequently. Distractions from alarms or warning messages on the MMI screen.	Staff responded that there was an additional pressure to drive within the specified limits and tolerances constantly, they responded that this is highly unlikely 100% of the time. Sometimes circumstances beyond their control dictate this.
2. Underload	There were a couple of reports of zoning out while driving under the protection in a CAWS area. The audible alarms and automatic emergency brake application when not acknowledged gave some drivers a sense of security. This is not the case outside of CAWS areas, the driver is in full control with no assistance from any technology or devices.	Since the start of the pandemic lockdown, drivers have reported incidents of lack of concentration. This can be attributed to fewer trains operating, less distraction and a greatly reduced service of trains running.
3. Recognition	The recognition of both of these conditions have been noted and reported. The majority of drivers have experienced underload in the last year. Overload isn't as common but some have reported that it is a factor affecting their role.	The high cognitive load required by driving staff is known and understood, how to deal with this effectively has been an issue. Some have suggested a course or training to manage these workload demands.

Table 7. Route knowledge/experience.

Theme three, is delivered below with examples and associated sub themes relating to route knowledge and experience.

Sub Theme	*Examples*	*Description*
1. *Lack of experience*	All drivers must complete 250 hrs in daylight driving and 40 hrs in darkness. Generally, drivers are trained up on one route initially and after a year or so learn another route. This experience will complete many aspects of driving not possible in the classroom.	Learning how to use platform monitors and gauging stopping distances. In all weather conditions these change dramatically, dealing with emergency situations and relating information to regulators/signalpersons. Making emergency brake applications, noted as very important by drivers.
2. *Situational awareness*	Driving in periods of fog or snow can have serious implications for a driver if they are not fully focused on the external environment. Mile posts at every ¼ mile are of benefit in such situations. Points of identification for approaching stations or signals should be noted.	In such inclement weather patterns, it may not be possible to (a) either see mile posts, (b) see any identifying points externally. Drivers should reduce speed and make use of MMI information and recall previous passed signals. Most drivers use these techniques even senior staff.
3. *Memory retention*	Respondents replied that working over a certain route continuously ensures a strong sense of familiarity with these routes. Even if it has been many months, recalling station limits and signals is done at ease. Recalling speed limits and areas of LRA come naturally.	Two drivers responded that their retention had reduced because of the introduction of technology like the MMI which announces approaches to stations with ample time to reduce speed. Some spend more time on the MMI screen rather than heads up driving.
4. *Familiarity*	Familiarity was described as knowing where the braking points in a section are, knowledge of all the speed limits and areas where heightened alertness is required. One claimed to know every signal number on their intercity route.	These are all factors in becoming familiar with a route, but having the experience and implementing the knowledge learned will also benefit the driver. Complacency can also play a part in being too familiar which may lead to an incident.
5. *Reduction of route knowledge*	There is a fear that route knowledge may be lost with the introduction of new semi-automated systems. Certain DMU units behave differently, some have better braking or acceleration attributes, a couple of drivers feel this will reduce their involvement while in control of the train.	The new hybrid system will take control of speeds and braking only if a driver fails to drive in the appropriate manner or does not activate the brakes when required. It is not fully automated, so driver participation is necessary.

Table 8. Cognitive skills.

Table eight represents the cognitive nature of the driving role.

Sub Themes	Examples	Description
1. Driver selection	According to the responses from the drivers, certain psychological suitability assessments were required and applies to their driving duties. Most agreed that these cognitive flexibility processes match the role in a strong manner, specifically maintaining concentration for long periods of time.	These assessments test the attentional resource capacity of candidates for the role of a driver. Four of the drivers responded that these skills could be expanded upon with the training and routine involved in train driving.
2. Attentional resources	Many of the drivers reported that their attentional level changes according to the demands and workload required. They said they noticed a decrease with the automation of some functions.	These changes have been supported by the findings of a new theory, MART in which a noticeable capacity for attention in a simulator environment was observed. The levels recorded decrease with the introduction of a secondary task.
3. Cognitive flexibility	The respondents indicated that there is a strong case for possessing cognitive flexibility in the cab. To be able to switch from one task to another quickly is imperative, with so many distractions from visual and audio mediums flexibility is paramount.	A couple of the staff commented that with newer technology and assistance that distractions may become more of an issue. They thought it could confuse and shift attention when it is not required.

Table 9. Implementation of safety related equipment.

Theme five addresses the data collected from the respondents concerning safety related equipment.

Sub Themes	Examples	Description
1. *Benefits*	There is a lot of positivity surrounding safety equipment. These can take the form of DRA's or the CAWS system and the door interlocking system on all trains. All of these were designed and installed to ensure passenger safety remains a priority throughout the rail network.	A number of the drivers spoke of the CCTV and how it provides a secondary view when on a curved line or on extremely busy trains. It is not uncommon for passengers to get caught in the automatic doors. This is seen as an absolute beneficial tool for assisting driving staff.
2. *Detracts from the driving role*	Some driving staff have indicated that they feel equipment is introduced without full consultancy with drivers and then used against them if not used correctly. Many of the drivers feel they 'dumb down' their role. Many of the responsibilities they once controlled are taken away from them.	Monitors at platform ends are an example of an aid that drivers now use. They assist in detraining passengers and especially busy trains. Some drivers have been sanctioned for not pulling up to them fully on a shorter train, they don't agree with some of the new policies laid out for this aid.
3. *Distrust*	There is some distrust regarding the live monitoring system DTE's use to monitor a driver. Five of the drivers thought that if a DTE had an issue with you that they could go out of their way to find something done incorrectly during the course of a journey.	The company has said this is not the case and is only being used for general monitoring of driving behaviour and in exceptional circumstances or an accident. Others argued that there is already an older recording unit onboard the trains for the same purpose, the OTDR.

Table 10. Implementation of Safety standards.

Theme six centres on acceptance and the introduction to new safety standards.

Sub Themes	Examples	Description
1. *Positivity towards standards*	There was a great deal of receptivity when asked about standards. In general, the drivers with the longest careers and much experience responded that they have seen a massive change in standards, also how they are perceived and implemented.	The most attributable factor has been the reduction in SPADS. Drivers have a safety notice board with the actual number of days since the last incident. Many feel that this inspires them to be more consistent in the role, three others said it makes them feel under pressure. Nobody wants to be the person who resets this important marker.
2. *Acceptance of industry needs*	All of the staff agreed that it is their duty to drive with care and attention all of the time. To adhere to industry standards and rules set out by the company. When a change to a rule or a standard is issued, it is usually because of an incident or some redundant policies which are not applicable today.	With ever changing technology and greater demands of TOC's drivers need to be adaptable and open to changes. Some drivers responded that they are happy with how things operate presently, unfortunately changes are a necessity and normally are for the benefit of the end user.
2. *Lack of familiarisation*	Quite a few drivers admitted that they are not fully briefed on certain new standards. Four said they are only aware when an incident has arisen that highlights the issue. DTE's do brief driving staff of any changes in procedures but it is the driver's responsibility to stay abreast of all documentation signed for.	Bi-yearly rules courses are held in Inchicore, these are designed for maximum learning and exposure to certain incidents for the driving staff. SPAD courses are held annually, short rules exams are also performed. If there is any doubt or queries, drivers should seek the advice of a DTE.

Chapter 6. Discussion

Discussion.

The outcomes from the thematic analysis of the questionnaires are reviewed here. Looking at the results and beginning to see a link between the research questions posed in chapter 2 and the data extracted from the respondents. Has there been a reduction in SPAD incidents, also has safety improved from levels seen 20 years ago?

1. Acceptance of new technology.

Reviewing the analysis from the respondents regarding acceptance of new technology, there is mostly agreement that it has improved the driving experience. CCTV and the DRA devices have been widely welcomed because of their positive attributes and merits as an aid for the role. Any potential trust issues were regarded as unmerited by means of investigation. MMI functions with their ability to alert fault locations on board are being embraced, this was also noted by (Woods, 2010) in their research of goal monitoring. These results address the research question posed and how they improve the driving role.

2. Mental workload.

There was some feedback concerning the CAWS system and how a few drivers felt complacent while driving in these areas. This resonates with a study compiled by (Wickens, 2003) in which it was observed while monitoring the workload. Underload in the role because of varying circumstances was noted and attributable to reduced services on the line, overload can be associated with excessive concentration on many different systems in the cab.

3. Route knowledge/experience.

Learning from real experiences has been a theme resounding from the majority of drivers in the study. There was some agreement that technology had a small role to play, but it was out road knowledge garnered from experienced mentors which supported the theory that actual route competence is gained. Simulators cannot provide this type of development for a driver, (Moloney, 2017) writes that these do however provide excellent stimulus and learning in a controlled environment.

4. Cognitive skills.

Driver selection and their cognitive abilities play a major role in the safe performance of train running. Technological advances in train modification and new signalling systems still rely heavily on human intervention. An understanding of how vital cognitive flexibility have become is seen in a number of studies, (Hickey, 2017), (Wickens, 2003) respectively. Much of the focus is placed on the driver's attentional resources in the cab which can lead to improved performance.

5. Implementation of safety related equipment

The introduction of the DRA appliance has dramatically reduced the amount of SASPADS since its launch. Reports from independent bodies including the (Commission, 2018) and the (European Union, 2018) have both shown significant decreases in this type of SPAD. This would suggest in the findings that there has indeed been a reduction of these incidents as shown by the statistics in each report.

6. Safety standards.

Acceptance and implementation of these new standards have made an impact regarding accident reductions in recent years. The UK has seen a 36% decrease in incidents in the years 2005-2018 (RSSB, 2020) and the EU have seen similar results with their statistics from their interoperability report (European Union, 2018). Unfortunately, new standard introductions are usually the outcome or result of an accident which then sees an appropriate response by the regulatory bodies. These modifications and updates benefit the travelling public regardless, these are then introduced and monitored by the relevant authorities for safter rail transport.

Outline of key findings.

Main theme		*Key findings*
Acceptance of new technology.		Generally accepted, some new introductions welcomed, perception of risk still a small issue for some, trust being built by use of same.
Mental workload.		Recognition of periods of both underload and overload, knowing how to adapt and perform in each scenario.
Route knowledge/experience.		Becoming familiar with traction units, implementing knowledge learned on route, having a robust awareness of certain situations, not to become complacent when familiarity sets in.
Cognitive skills.		Focus attention on in cab display units while also being aware of external environment, remain focused with the addition of other tasks.
Implementation of safety related equipment.		Beneficial in the driver role, most agree it has improved certain aspects of driving, distrust of recording devices but are necessary by law on all traction units.
Safety standards.		Positive response to new and updated standards, drivers are responsible for safe operation of trains, any unfamiliarity to be addressed by additional training and clarification from DTE's.

Table 11, Key findings from driver's questionnaires.

The findings above are a summary of the respondent's views and feedback from all aspects covered in the questionnaire.

Research limitations.

There were of course certain limitations in the collation of this data, with the current pandemic and level 5 restrictions in place gaining the required access to relevant participants proved sometimes difficult. Examination of other countries safety records and SPAD incidents were invaluable towards making comparisons with Irelands record on safety improvement. Unfortunately, there have not been many studies carried out to fully examine in detail the precise nature of each incident and their primary factors. Information was bundled together to give an aggregate figure in each region in the reports and articles researched.

Limited access to driving staff who operate in the CAWS area placed a constraint on this research. The possibility of an interview process as addressed by (Queirós, 2017), interviews provide detailed information and they offer the opportunity to ask follow-up questions, probe additional information, justify previous answers, and establish a connection between several themes. Holding interviews may have provided different responses than the questionnaires provided but it was not possible to secure access. This does not belittle the deep exploratory qualitative analysis of the data provided.

Examination of human factors and how they are perceived in the everyday driving role found that there are attentional levels of distraction that could be researched further. The driver's involvement and participation with new technology also is a worthwhile study when considering the impact on the driving role. Understandably there are limitations on how feasible this could be under the present circumstances; maybe in the near future it could be a possibility.

Conclusions.

The objective of this dissertation was to ascertain that safety in rail travel has improved and incidents of SPADS have decreased in the previous twenty years. The EU, the UK and Ireland have all seen much improved standards, along with accident and incidents reductions in this period. Higher levels of monitoring, improved staff training along with technological advances have proved to be successful factors in this accomplishment.

The supporting evidence gathered from many different sources and studies have resulted in a conclusion of positive results by TOC's which have been measured in significant accident reductions. In the UK for the years 2005-2018 a 36% decrease was noted, across the EU28 states they have seen 27% reductions in accidents in the years 2010-2018. Ireland has not had any loss of life in the years 2004-2016 as a result of any railway accidents. Studies by (European Union, 2018) and (RSSB, 2020) have both pointed to significant investment in technology, in new signalling systems and safety related infrastructure as some of the reasons for these statistics.

Irish Rails new hybrid train protection system will enhance their continued safety record with its traffic management system, this will have control of all signalling on the rail network and mitigate some previous hazards. Such investments are a priority for the company and also underpin their commitment to a safer and greener future of rail travel.

Conclusions drawn from the questionnaires with the driving staff at Irish Rail have given an insight into what improvements and expectations they have encountered in their positions. Many said that safety as a number one priority is evident daily and that the company's commitment to ensuring these high standards are met and have been realised. Some have experienced a major change in how training is delivered, how new technology has improved the driving role and areas such as human factors and cognitive skills are developed in the future. The role of a train driver has become more optimistic with the contribution, support and future investment in the railways.

Ethical considerations.

The research poses very little or no ethical risk to the participants involved or the company they represent. This questionnaire was developed with the aim of avoiding a risk of confidentiality. None of the participants were asked to divulge any confidential information regarding their organisations which may be deemed not for public disclosure. There was no deception of any form and no vulnerable persons were involved or participated. In addition to understanding the discourse of academic research, being aware of what constitutes ethical research is an essential part of planning for a research project (Marcelle, 2015). With this being said, the author has considered any ethical issues fully in relation to this study, none were found and participation from the respondents was therefore understood with their informed consent.

References.

Adams, A. a. C. A. L., 2008. *Questionnaires, in-depth interviews and focus groups,* Cambridge: Open University.

Admin, 2016. *Baker Tilly.* [Online]
Available at: https://www.bakertilly.ie/ireland-small-railways/
[Accessed 11th Feb 2021].

Aecom, 2017. *www.irishrail.ie/IrishRail/media/Imported/.* [Online]
Available at: https://www.irishrail.ie/IrishRail/media/Imported/IrishRail_28FebFinal_Part11.pdf
[Accessed 8th March 2021].

Baillargeon, J., 2020. *railwayage.* [Online]
Available at: https://www.railwayage.com/news/fra-rdt-using-ai-to-improve-safety-2/
[Accessed 10th March 2021].

Balfe, N., 2016. *A framework for human factors analysis of railway on-train data.* Prague, HFES-Europe Chapter Conference,.

Banks, A. V., 2016. *Human Factors Considerations In the Design and Development of Highy Automated Driving Systems,* Southampton: University of Southampton.

BBC, 2016. *BBC News.* [Online]
Available at: https://www.bbc.com/news/world-europe-37936198
[Accessed 12th March 2021].

Boukerche, A. Y. T. P. S., 2020. Artificial intelligence-based vehicular traffic flow prediction methods for supporting intelligent transportation systems. *Computer networks,* Volume 182, pp. 2-21.

Braun, V. &. C. V., 2006. Using thematic analysis in psychology.. *Qualitative research in psychology,* Volume 3, pp. 77-101.

Carretta, T. S. P. D. C. J. &. R. M. J., 1996. Prediction of situational awareness in F-15 pilots.. *International Journal of Aviation Psychology,,* Volume 6, pp. 21-41.

Chapman, C., 2019. *DEVELOPING A LOCATION SPECIFIC RISK MODEL FOR IRISH RAIL,* Kent: Sotera.

Cheryl A. Bolstad, M. R. E. A. M. C. C. D. H., 2010. Evaluation of Computer-Based Situation Awareness Training for General Aviation Pilots. *THE INTERNATIONAL JOURNAL OF AVIATION PSYCHOLOGY,,* 20(3), pp. 269-294.

Commission, R. R., 2018. *Statement of Strategy,* Dublin: Commission For railway Regulation.

Cooper, R. R. J. C. a. S. F., 2012. Grounded Theory of Inductive Qualitative Research Education: Results of a Meta-Data-Analysis. *The Qualitative Report,* 18(8), pp. 1-26.

Di Claudio Mariano, A. F. G. M. S. M. P. N., 2014. *Model based development of an Automatic Train Operation component for Communication Based Train Control.* Florence, University of Florence.

Eireann, I., 2019. *Iarnrod Eireann annual report 2019,* Dublin: Irish Rail.

Europa, C., 2021. *European Commission.* [Online]
Available at: https://ati.ec.europa.eu/news/malaga-launches-europes-first-trial-driverless-electric-

buses
[Accessed 23rd March 2021].

European Union, A. F. R., 2018. *Report on Railway Safety and Interoperability in the EU,* Luxemburg: EU agency For Railways.

European, C., 2018. *Mobility and Transport.* [Online]
Available at: https://ec.europa.eu/transport/modes/rail/ertms_en
[Accessed 07th March 2021].

European, C., 2020. *Deployment of ERTMS on Core and Comprehensive Networks,* Luxemburg: European Commission.

Fan Jialin, A. P. S., 2018. *A Preliminary Review of Fatigue Among Rail Staff,* Seattle: Frontiers in Psychology.

Farrington-Draby Trudy, W. R. J., 2006. The nature of expertise: A review. *Applied Ergonomics,* 37(1), pp. 17-32.

Feehan, J. V., 2019. *iaemo.ie.* [Online]
Available at: https://www.iaemo.ie/wp-content/uploads/2019/06/accident_buttevant.pdf
[Accessed 06th February 2021].

Giesemann, S., 2013. *AUTOMATION EFFECTS IN TRAIN DRIVING WITH TRAIN PROTECTION SYSTEMS ASSESSING PERSON- AND TASK-RELATED FACTORS,* Bonn: Rail Human Factors.

Glennon, G., 2014. *NCIRL.* [Online]
Available at:
https://library.ncirl.ie/items?query=author%3A%28Glennon%2C+Geraldine%29&target=catalogue
[Accessed 20th March 2021].

Global, r. r., 2019. *https://www.globalrailwayreview.com/.* [Online]
Available at: https://www.globalrailwayreview.com/news/89548/rail-safety-concerns-red-signals/
[Accessed 11th March 2021].

Grandjean, K. H. E. K. a. E., 1997. *Fitting The Task To The Human.* 5th ed. London: Taylor and Francis.

Groeger, C. L. B. A. R. D. M. P. S. M. B., 2001. *Pilot study of train drivers eye movements,* Surrey: University of Surrey.

Gulhane, M. M. P. P., 2014. INTELLIGENT FATIGUE DETECTION AND AUTOMATIC VEHICLE CONTROL SYSTEM. *International Journal of Computer Science & Information Technology ,* 6(3), pp. 87-92.

Heaton, J., 2008. Secondary analysis of qualitative data: an overview.. *Historical Social Research,,* 33(3), pp. 33-45.

Hickey, R. A. C. D. M., 2017. *Selecting high performing train drivers: the role of attention and cognitive flexibility.* London, The Sixth International Human Factors Rail Conference.

Ireland, T. f., 2018. *Irishrail.ie.* [Online]
Available at: https://www.irishrail.ie/Admin/IrishRail/media/Content/projects-and-investments/DART-brochure.PDF
[Accessed 11th Feb 2021].

Iridiastadi, H., 2020. Fatigue in the Indonesian rail industry: A study examining passenger train drivers. *Applied Erogonomics,* Volume 92, pp. 2-7.

Klein, G., 2008. Naturalistic Decision Making. *Human Factors The Journal of the Human Factors and Ergonomics Society,* Issue June, pp. 456-460.

Li, G. H. W. M., 2005. Driver detection and recognition of lineside signals and signs at different approach speeds.. *Cogn Tech Work,* Volume 8, pp. 30-40.

Lopez, J. R. W. D., 2010. *LA Times.* [Online]
Available at: https://www.latimes.com/archives/la-xpm-2010-jan-22-la-me-metrolink22-2010jan22-story.html
[Accessed 12th March 2021].

Lord Cullen, 2000. *Jesip.co.uk.* [Online]
Available at:
https://www.jesip.org.uk/uploads/media/incident_reports_and_inquiries/Ladbroke%20Grove%20Rail%20Inquiry%20Report%20Part%201.pdf
[Accessed 11th March 2021].

Marcelle, C., 2015. The Praxis of English Language Teaching and Learning (PELT). In: *The Praxis of English Language Teaching and Learning (PELT).* London: Sense Publishers, pp. 55-73.

McLeod Ronald W., G. H. W. N. M., 2005. Analysing and modelling train driver performance. *Applied Ergonomics,* 36(1), pp. 671-680.

Moloney, J. W., 2017. *Applying Simulation Techniques to Train Railway Traction Drivers,* Birmingham: University of Birmingham.

Monk Alice, C. K. H. G. A. F. ,. A. T., 2019. *Achieving a step change in route knowledge Management.* [Online]
Available at: https://publications.ergonomics.org.uk/uploads/Achieving-a-step-change-in-route-knowledge-management.pdf
[Accessed 04th March 2021].

Mykola, Z., 2019. *Railtech.com.* [Online]
Available at: https://www.railtech.com/infrastructure/2019/12/20/ireland-to-invest-1-billion-euros-in-rail-infrastructure/?gdpr=accept
[Accessed 11th Feb 2021].

Naghiyev, A., 2017. *Human factors of train driving with incab control and automation technology,* Nottingham: University of Nottingham.

NTA, 2011. *Annual Report & Financial Statements 2011,* Dublin: National transport agency.

NTA, 2016. *Annual report 2016,* Dublin: National transport agency.

Parkes, M. A., 2006. An Invsetigation of train driver visual startegies. *Cognition Technology and Work,* Volume 8, pp. 15-29.

Pasquini A, A. R. L. S., 2004. A methodology for the analysis of SPAD. *Safety Science,* 42(2), p. 439.

Queirós, A. D. F. A. F., 2017. STRENGTHS AND LIMITATIONS OF QUALITATIVE AND QUANTITATIVE RESEARCH METHODS. *European Journal of Education Studies,* 3(9), pp. 369-386.

Railway, T., 2019. *The Railway Technical Website.* [Online]
Available at: http://www.railway-technical.com/trains/rolling-stock-index-l/train-equipment/brakes/vacuum-brakes.html
[Accessed 9th March 2021].

RAIU, 1983. *Accident on thr CIR railway near Cherryville junction,* Dublin: CIE.

Richman, L. W. K. S. W. S. D. F., 1999. A Meta-Analytic Study of Social Desirability Distortion in Computer- Administered Questionnaires, Traditional Questionnaires, and Interviews. *Journal of Applied Psychology,* 84(5), pp. 754-775.

Roth, E. &. M. J., 2009. *Technology implications of a cognitive task analysis for locomotive engineers. Washington D C: U.S. Department of Transportation,* Washington DC: Dept. of Transportation.

RSSB, 2012. *Development of an education programme on the risk of using mobile phones and electronic communication devices in the railway industry,* London: RSSB.

RSSB, 2020. *RSSB.co.uk/.* [Online]
Available at: https://www.rssb.co.uk/research-catalogue/CatalogueItem/T1135
[Accessed 21st March 2021].

Ruggiano, N. P. E. T., 2019. Conducting secondary analysis of qualitative data: Should we, can we, and how?. *Qualitative Social Work,* 18(1), pp. 81-97.

Saunders, N. M. L. P. T. A., 2019. *Research gate.* [Online]
Available at:
https://www.researchgate.net/publication/330760964_Research_Methods_for_Business_Students_Chapter_4_Understanding_research_philosophy_and_approaches_to_theory_development
[Accessed 01 April 2021].

Sheridan, T. W. C. P. R., 2008. Situational awareness, mental workload, and trust in automation.. *Journal of cognitive engiineering and decision making,* 2(2), pp. 140-160.

Strategy, 2., 2021. *Iarnrod Eireann.* [Online]
Available at: https://www.irishrail.ie/Admin/IrishRail/media/Content/About%20Us/IE-Strategy-2027_Final_One-Page_20210114.pdf
[Accessed 13th March 2021].

Stromberg, J., 2015. *VOX.com.* [Online]
Available at: https://www.vox.com/2015/5/14/8606195/train-safety-driving-crashes
[Accessed 12th Feb 2021].

Sutton, J. A. Z., 2015. Qualitative Research: Data Collection, Analysis, and Management. *The Canadian Journal Of Hospital Pharmacy,* 68(3), pp. 226-231.

Terry, G. ,. N. H. V. C. a. V. B., 2017. The Sage handbook of qualitative research in psychology 2nd Ed. In: *The Sage handbook of qualitative research in psychology 2nd ED.* London: Sage, pp. 17-37.

Tschirner, S. A. A. S. B., 2013. *Designing train driver advisory systems for situation awareness..* London, 4th International Conference on Rail Human factors.

Vazquez-Jose-Iglesias, F. R., 2016. *A Case Study of the High-speed Train Crash Outside Santiago de Compostela, Galicia, Spain.* [Online]
Available at: https://www.researchgate.net/publication/299643510_A_Case_Study_of_the_High-

speed_Train_Crash_Outside_Santiago_de_Compostela_Galicia_Spain
[Accessed 03rd March 2021].

Wall, M., 2016. *Irish Times.* [Online]
Available at: https://www.irishtimes.com/business/financial-services/iarnr%C3%B3d-%C3%A9ireann-s-train-signalling-systems-outdated-report-1.2914825
[Accessed 08th March 2021].

Wickens, D. C. H. J., 2003. Attentional Models of Multitask Pilot Performance Using Advanced Display Technology. *The Journal of the Human Factors and Ergonomics Society,* 45(3), pp. 360-380.

Wilson John R., B. N. A. M. a. T. C., 2005. Rail Human Factors - Supporting the integrated railway. In: *Rail Human Factors.* London & New York: Routledge, p. 25.

Wilson R. John, N. J. B., 2005. Human factors in support of a successful railway: a review. *Cogn Tech work,* 8(005), pp. 04-14.

Woods, D. D. &. B. M., 2010. Hollnagel's test: being 'in control' of highly interdependent multi-layered network systems.. *Cognition, technology and work,,* Volume 12, pp. 95-101.

Woods, M., 2012. *Rssb.co.uk/.* [Online]
Available at: https://www.rssb.co.uk/en/research-catalogue/CatalogueItem/T869
[Accessed 15th March 2021].

Wynne, A. R. B. V. S. M. P., 2019. Systematic review of driving simulator validation studies. *Safety science,* Volume 117, pp. 138-151.

York, 2018. *Tork Cuny.* [Online]
Available at: https://www.york.cuny.edu/wac/for-students/handouts-for-specific-courses-and-disciplines/sociology/questionnaires-and-interviews.pdf
[Accessed 12th March 2021].

Young, S. M. &. S. N., 2002. *Malleable Attentional Resources Theory: A new explanation for the effects of mental,* London: Brunel University.

Zoer, I. S. J. K. &. F.-D. M. H. W., 2014. *Taylor & Francis online.* [Online]
Available at: https://www.tandfonline.com/doi/abs/10.1080/00140139.2014.938130
[Accessed 4th March 2021].

Appendices.

Appendix 1. Driver role Analysis

The key technical skills of a driver's job are to:

1. Adhere to signals, trackside signs, boards and indicators. This requires:

1.1 Vigilance to notice the informational artefacts;

1.2 Recollection and application of rules and route knowledge;

1.3 Ability to assimilate information;

1.4 Decision making skills;

1.5 Ability to mount a fast response to the information.

2. Monitor the trackside and the track ahead for trackside workers, trespassers and obstructions. The requirements for this task group are:

2.1 Vigilance;

2.2 Fast reactions;

2.3 Decision making skills.

3. Monitor and adjust the speed of the train. This necessitates:

3.1 Observation of the speedometer, and the assembly of data from late notice cases, weekly circulars and lineside signage into information;

3.2 Cognisance of train make up, train performance and metrics, *permissible speed* and gradients.

4. Respond to advisory systems. This requires vigilance to ensure that a signal is not missed and that there is correspondence between the displayed aspect on the *ADU* and the lineside signal. This process involves recollection and application of route knowledge;

5. Respond to the SCE. This involves application of traction knowledge;

6. Attendance to informational cues. The requirements for this task group are:

6.1 Attendance to internal inputs, e.g., TDMS, train radio messages and passenger communications system;

6.2 Attendance to external cues. While accepting that staff needs to be technically competent; on its own, it is insufficient for effective task performance. Complimentary non-technical competence is also required. This skill set includes:

1. Situational awareness:

1.1. Attention to detail;
1.2. Overall awareness;
1.3. Ability to maintain concentration;
1.4. Ability to retain information;
1.5. Ability to anticipate risk;
2. Conscientiousness:
2.1. Ability to apply a systematic and thorough approach;
2.2. Constant checking;
2.3. The display of a positive attitude towards rules and procedures;
3. Communication:
3.1. Ability to listen and take the intended message out of the verbiage;
3.2. Ability to communicate clearly and assertively;
3.3. Willingness to share information;
4. Decision making and action;
4.1. Ability to make effective and timely decisions;
4.2. Possession of diagnostic and problem-solving skills;
5. Cooperation and working with others:
5.1. Considers others' needs;
5.2. Supports others;
5.3. Treats others with respect;
5.4. Ability to deal with conflict or aggressive behaviour;
6. Workload management:
6.1. Ability to multi-task and to selectively attend;
6.2. Ability to prioritise;
6.3. Ability to remain calm under pressure;
7. Self-management:
7.1. Is motivated;
7.2. Is confident and can take the initiative;
7.3. Maintains and develops skills and knowledge;
7.4. Is prepared and organised;
8. Fatigue management:
8.1. Can identify symptoms of fatigue;
8.2. Recognises effects of fatigue;
8.3. Can implement coping strategies.

Source: RSSB (2012).

Appendix 2. Questionnaire information sheet.

Thank you very much for agreeing to participate in this study.
As part of my programme of study for a Masters in Management, I am required to complete a dissertation. The purpose of a dissertation is to identify pertinent issues relating to a particular topic through a review of the current academic literature, and to undertake primary research to explore actual experiences of those issues.

The working title of my dissertation is "An examination of the modern railways continuous efforts to enhance safe rail travel", and the themes I would like to examine are as follows:

1. What are the most important changes in technology that affect your daily driving?

2. How would you describe the introduction of safety related equipment on board trains?

3. Would you say driving has become heavily reliant on computer aided support systems and why?

4. As a driver, how would you describe the safety standards that apply to the driving grade?

5. Working as an DTE how would you describe the training and monitoring of drivers from trainee to full driving position?

6. Has fatigue ever had an impact on your driving capabilities at any time?

7. Does your training provide for failure of any safety related equipment to allow you to complete a journey?

8. Are there any limitations or barriers when bringing a safety issue to your manager?

9. Has there been a time where you may have lost situational awareness and the technology installed has helped you resolve the issue?

10. Would you say there is a positive safety culture reinforced by the safety management system?

11. Do you think the extensive training and job design has enabled you to adhere to the professional standards?

12. How confident are you that the high standards achieved in safety within Irish Rail will be sustained into the future?

13. How would you view your cognitive skills in any aspect of train driving?

14. In the DTE grade how important is it to keep up with the latest standards introduced by the commission for railway regulation?

In order to elicit your views, I would appreciate if you would participate in a questionnaire. The information provided in the questionnaires will be typed up, and will be used to collate date for research purposes only. However, your name and your organisations details will be anonymised in the dissertation. (For the purposes of assessment and marking of the dissertation, the examiner may require verification of authenticity of research data.).
As is typically the case with academic research, the final dissertation including the anonymised research data and findings, will be held by the college (NCIRL) in electronic and

hard copy format, and will be available to other researchers in line with current data sharing practices.
If you have any questions about the research or dissertation at any stage, please do not hesitate to contact me.
Many thanks,

Richard.

Consent Form

- I the undersigned have read and understood the Study Information Sheet
- I have been given the opportunity to ask questions about the study
- I understand that taking part in the study will include being questioned
- I understand that personal details such as name and organisation address will not be revealed in the dissertation
- I understand that my words may be quoted in the dissertation but my name will not be used
- I understand that I can withdraw from the study at any time

Participant: ____________________________________ Date: ________________
Researcher: ____________________________________ Date: ________________
Participant number: _________
Participant Employer number: __________

Source (Glennon, 2014).

Appendix 3. SPAD statistics 1995 - 2003

Appendix 11: Percentage of all SPADs by Error Type (1995 - 2003)

	1996/'97	1997/'98	1998/'99	1999/'00	2000/'01	2001/'02	2002/'03	Average	Type of error (based on SA model)
Anticipation of signal clearance	5%	6%	6%	5%	5%	5%	5%	5·29%	Projection
Failure to check signal aspect	18%	18%	17%	20%	16%	20%	17%	18·00%	Perception
Failure to locate signal	10%	7%	9%	8%	12%	12%	7%	9·29%	Perception
Failure to react to caution signal	20%	25%	24%	27%	27%	25%	15%	23·29%	Action
Ignorance of rules or instructions	1%	1%	2%	1%	3%	0%	1%	1·29%	Comprehension
Violation of rules or instructions	5%	4%	6%	7%	8%	7%	5%	6·00%	Model does not apply
Wrong information given	2%	2%	2%	1%	2%	3%	1%	1·86%	Perception (communication)
Ambiguous or incomplete information given	2%	1%	1%	3%	3%	1%	3%	2·00%	Perception (communication)
Information not given	0%	0%	0%	0%	1%	0%	0%	0·14%	Perception (communication)
Correct information given but was misunderstood	1%	1%	1%	1%	1%	2%	1%	1·14%	Perception (communication)
Viewed wrong signal	7%	5%	6%	5%	5%	8%	5%	5·86%	Perception/comprehension
Viewed correct signal but misread aspect	2%	2%	2%	5%	3%	3%	3%	2·86%	Perception/comprehension
Misread previous signal	1%	1%	2%	1%	1%	2%	0%	1·14%	Perception
Misjudged train behaviour	8%	8%	7%	5%	3%	3%	3%	5·29%	Comprehension/decision making
Misjudged environmental conditions	8%	7%	7%	5%	4%	3%	3%	5·29%	Comprehension/decision making
Other reason	5%	6%	3%	4%	2%	1%	0%	3·00%	
Equipment or environment (not the driver)	6%	3%	4%	3%	3%	3%	2%	3·43%	External factors
Not yet categorised	1%	3%	1%	0%	0%	1%	26%	4·57%	

Based on: RSSB (2003)

Source (Moloney 2017).

	2005	2006	2007	2008	2009
Total SPADs involving I.É.'s drivers	40	36	30	22	21
SPADs at shunting discs/signals	7	9	7	7	5
Shunting SPADs as a proportion of total	17·5%	25%	23·3%	31·8%	23·8%
Proportion of SPADs at shunting signals	23·5%				
Number of overruns ≥ 180 m at shunting signals	1	0	0	1	0
SPADs at running signals	33	27	23	15	16
Number of SPADs at running signals for which data is available	32	23	22	15	16
Number of overruns ≥ 180 m at running signals	5	4	5	3	2
Proportion of SPADs at running signals where the overrun was ≥ 180 m	17·6%[38]				
Mean exceedence of the LMAs for running signals (m)	70	189	116	119	82
Standard deviation of exceedences of LMAs for running signals (m)	108·6	466·5	124·3	139·9	148·9
Probability of a SPAD exceeding the overlap (180 m) of a running signal	15·6%	17·4%	22·7%	20·0%	12·5%

Source (Moloney 2017).

Appendix 4. Decision making.

Decision making in rail as we have already noted, during normal operations in the UK rail industry decision making tends to be process-driven and deferred up a chain of command. This means that front-line staff may only rarely face the opportunity or imperative to make decisions on their own initiative when degraded situations arise. Decision-making training offered to staff tends to be very limited, and decision-making tools are not used. However, there have been some attempts to support staff and equip them with the skills to make effective decisions (RSSB, 2020).

Non-technical skills (NTS) are widely recognised across the industry as important skills for safety critical roles, although often the details and training do not reach those that may

(Woods, 2012) action'. This focuses on effective decisions, timely decisions, and diagnosing and solving problems (Non-Technical Skills, 2012). It also suggests following a STAR model when making decisions (Figure 1). | Development of an operational decision-making model for abnormal working 33 Figure 1 - STAR Decision Model.

Figure 1 - STAR Decision Model

The STAR model gives a high-level structure to decisions. The decision models that are examined in this document follow the same underlying structure but provide more detail, particularly in the 'think' section of this model. While NTS touches upon decision making, it is not known how many front-line staff receive this training, nor how it is delivered or how frequently it is refreshed. Furthermore, the decision module of the NTS training is limited.

Source (RSSB 2020).

Appendix 5. Passenger risk in the EU

The latest National Reference Values for passenger fatalities adopted for the EU Member States are – for the purposes of illustration – listed below. The NRVs are calculated from the figures the Member States submitted for the years 2004-2007. It should be noted that the definitions adopted by various Member

States still exhibited differences during these years and for these reason objective comparisons of the NRVs for the various Member States are not yet feasible. The European obligation to make use of the Common Safety Indicators will result in the gradual disappearance of these differences in the coming years. This will improve the feasibility of comparisons of the figures. However, and with the necessary reservations in view of the different definitions used by the different Member States, the latest rankings reveal that the Netherlands is sixth and fifth in the passenger safety rankings.

Member State	NRV (passenger train kilometres)
1. Sweden	5.70
2. Ireland	6.22
3. United Kingdom	6.22
4. Denmark	7.55
5. Germany	10.9
6. Netherlands	**11.7**
7. Slovenia	11.8
8. Slovakia	17.7
9. France	21.9
10. Finland	26.8
EURV	**34.4**

Member State	NRV (passenger kilometres)
1. Sweden	0.0557
2. Ireland	0.0623
3. United Kingdom	0.0623
4. Denmark	0.0903
5. Netherlands	**0.0941**
6. France	0.109
7. Germany	0.11
8. Slovenia	0.175
9. Luxembourg	0.225
10. Finland	0.248
EURV	**0.288**

Source: European Railway Agency

Appendix 6. Irish Rail fatality and injury statistics 2006 – 2016.

Category	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Trend
Railway operations: passenger fatal injuries												
Fatal injury to passenger due to a train accident, not at level crossing	0	0	0	0	0	0	0	0	0	0	0	
Fatal injury to passenger due to a train accident at level crossing	0	0	0	0	0	0	0	0	0	0	0	
Fatal injury to passenger travelling on a train, other than in train accident	0	0	0	0	0	0	0	0	0	0	0	
Fatal injury to passenger attempting to board or alight from train	0	0	0	0	0	0	0	0	0	0	0	
Railway infrastructure: third party fatal injuries												
Fatal injury to third party at a level crossing involving a train	0	1	1	0	2	0	0	0	0	0	0	
Fatal injury to third party at a level crossing not involving a train	0	0	0	0	0	0	0	0	0	0	0	
Railway operations: employee fatal injuries										0	0	
Fatal injury to employee at a level crossing due to train in motion	0	0	0	0	0	0	0	0	0	0	0	
Fatal injury to employee due to train in motion (other than at a level crossing)	0	0	0	0	0	0	0	0	0	0	0	
Fatal injury to employee not due to train in motion	0	0	0	0	0	0	0	0	0	0	0	
Railway infrastructure: employee fatal injuries												
Fatal injury to employee at a level crossing due to train in motion	0	0	0	0	0	0	0	0	0	0	0	
Fatal injury to employee due to train in motion (other than at a level crossing)	0	0	0	0	0	0	0	0	0	0	0	
Fatal injury to employee not due to train in motion	0	0	0	0	0	0	0	0	0	0	0	
Railway operations: fatal injuries to other persons												
Fatal injury due to train in motion not at level crossing	0	1	0	0	0	0	0	0	0	0	0	
Fatal injury to customer or visitor, no train involved	0	1	0	0	0	0	0	0	0	0	0	
Fatal injury involving train in motion on railway or level crossing where trespass or suspicious death was indicated	7	5	8	3	8	7	5	4	6	2	5	
Railway operations: non fatal injuries to passengers												
Injury to passenger travelling on train due to a railway accident not at level crossing	0	0	0	2	0	0	0	0	0	0	0	
Injury to passenger travelling on train due to railway accident at level crossing	0	0	0	0	0	0	0	0	0	0	0	
Injury to passenger attempting to board or alight from train	55	50	43	17	64	46	41	39	45	48	79	
Injury to passenger travelling on train, other than due to a railway accident	41	35	22	40	28	10	27	43	18	15	31	
Railway infrastructure: third party non fatal injuries												
Third party at level crossing injury involving a train	0	1	0	0	0	1	2	0	0	0	0	
Level crossing user injury not involving a train	0	1	1	1	0	2	5	1	0	0	0	
Railway infrastructure: non fatal injuries to other persons												
Injury to customer or visitor to premises	72	70	54	56	85	113	116	193	205	146	192	
Injuries to other persons including unauthorised persons	0	1	0	0	0	0	5	3	0	1	2	
Railway operations: non fatal employee injuries												
Employee lost time injury involving train movement or train accident	15	7	8	13	11	7	13	5	21	3	1	
Employee lost time injury while working on railway not due to train in motion	38	36	37	31	27	22	32	39	43	32	30	
Railway infrastructure: non fatal employee injuries												
Employee lost time injury involving train movement or train accident	0	1	1	0	1	2	1	0	0	0	0	
Employee lost time injury while working on railway not due to train in motion	31	42	42	34	30	23	32	41	25	6	23	
Employee lost time injury while working at level crossing not due to train in motion	2	4	0	0	0	0	1	1	2	0	3	
Entity in charge of maintenance and maintenance workshops: non fatal employee injuries												
Employee lost time injury involving train movement or train accident	0	0	0	1	0	0	0	0	0	0	0	
Employee lost time injury while working on railway not due to train in motion	30	36	27	21	10	18	10	14	18	13	11	

Figure 6 - IÉ Operational fatality and Injury Statistics by year

Source, Report railway safety performance in Ireland 2016.

Appendix 7. Thematic analysis.

Six phases of thematic analysis (Braun & Clarke, 2006)

This should not be viewed as a linear model, where one cannot proceed to the next phase without completing the prior phase (correctly); rather analysis is a recursive process.

1) Familiarisation with the data: is common to all forms of qualitative analysis – the researcher must immerse themselves in, and become intimately familiar with their data; reading and re-reading the data (and listening to audio-recorded data at least once, if relevant) and noting any initial analytic observations.

2) Coding: is also a common element of many approaches to qualitative analysis (see Braun & Clarke, 2012a, for thorough comparison), this involves generating pithy labels for important features of the data of relevance to the (broad) research question guiding the analysis. Coding is not simply a method of data reduction. It is also an analytic process, so codes capture both a semantic and conceptual reading of the data. The researcher codes every data item and ends this phase by collating all their codes and relevant data extracts.

3) Searching for themes: A theme is a coherent and meaningful pattern in the data relevant to the research question. If codes are the bricks and tiles in a brick and tile house, then themes are the walls and roof panels. Searching for themes is a bit like coding your codes to identify similarity in the data. This 'searching' is an active process; themes are not hidden in the data waiting to be discovered by the intrepid researcher, rather the researcher construct themes. The researcher ends this phase by collating all the coded data relevant to each theme.

4) Reviewing themes: Involves checking that the themes 'work' in relation to both the coded extracts and the full data-set. The researcher should reflect on whether the themes tell a convincing and compelling story about the data, and begin to define the nature of each individual theme, and the relationship between the themes. It may be necessary to collapse two themes together or to split a theme into two or more themes, or to discard the candidate themes altogether and begin again the process of theme development.

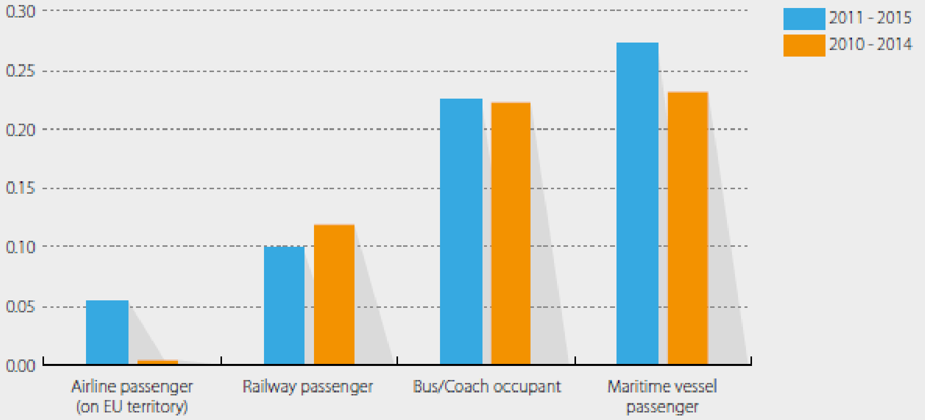
5) Defining and naming themes: Requires the researcher to conduct and write a detailed analysis of each theme (the researcher should ask 'what story does this theme tell?' and 'how does this theme fit into the overall story about the data?'), identifying the 'essence' of each theme and constructing a concise, punchy and informative name for each theme.

6) Writing up: Writing is an integral element of the analytic process in TA (and most qualitative research). Writing-up involves weaving together the analytic narrative and (vivid) data extracts to tell the reader a coherent and persuasive story about the data, and contextualising it in relation to existing literature.

Source (Dissertation Notes 2021).

Appendix 8. Passenger fatalities risks.

Figure 49: Passenger fatality risk (passenger fatalities per billion passenger-km) for different modes of transport, EU, 2010-2014 and 2011-2015



Source: CARE database, Eurostat, ERA, EASA, EMSA annual reports

Figure 50: Passenger fatality risk (passenger fatalities per billion passenger-km) for different modes of land transport and type of user, EU, 2011-2015

User	Fatalities per billion passenger-km (2011-2015)	Fatalities per billion passenger-km (2010-2014)
Railway passenger	0.100	0.119
Bus/Coach occupant	0.225	0.222
Car occupant	2.670	2.820
Car driver	1.820	n/a
Car passenger	0.850	n/a
Powered two-wheelers	37.800	39.950

Source: CARE database, Eurostat, ERA, EASA, EMSA annual reports

Source Report on Railway Safety and Interoperability in the EU (2018).

Appendix 9. Spad reductions at Irish Rail 2003 - 2016

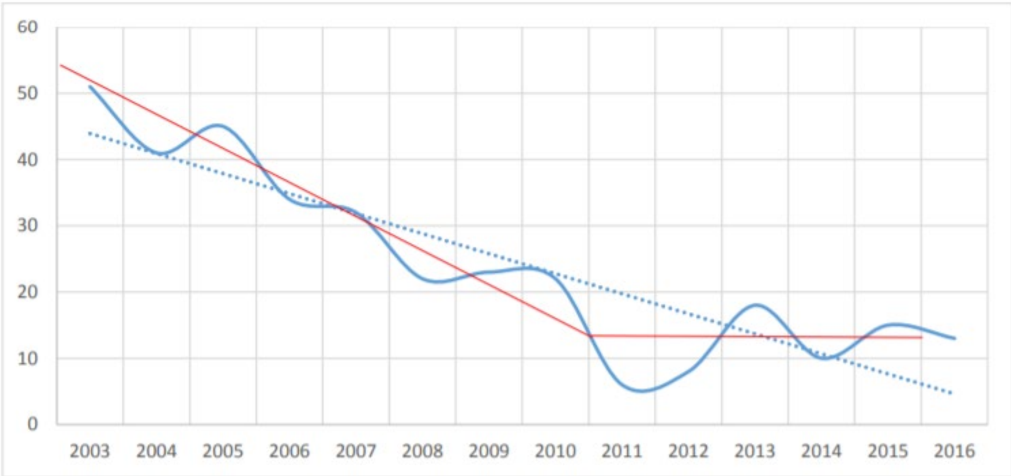
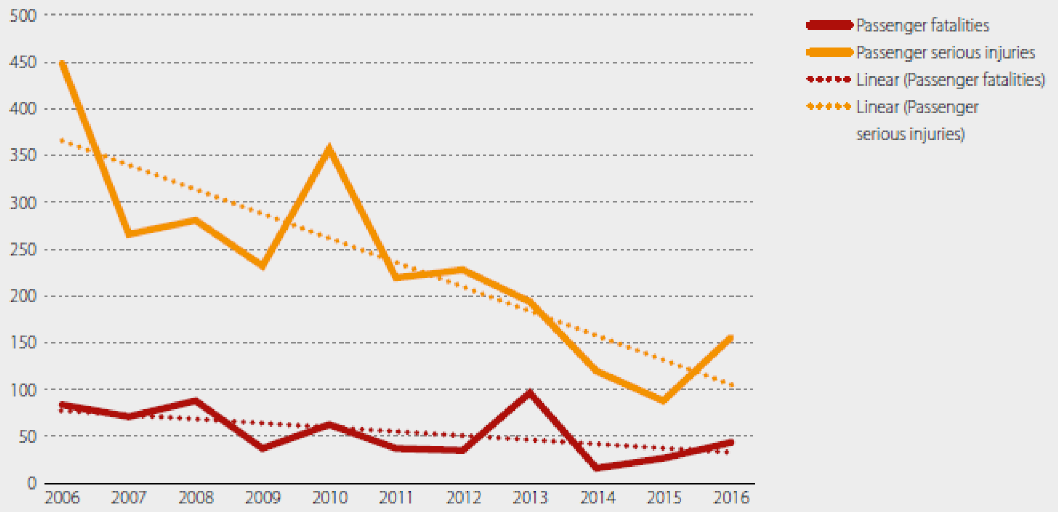


Figure 16 - IÉ SPADs by year

Source, Railway Safety Performance in Ireland 2016 report. CRR.ie

Appendix 10. Accidents and incidents reductions 2006-2016

Figure 12: Passenger fatalities and serious injuries with trend lines, EU 28, 2006-2016



Source: ERAIL

Source Report on Railway Safety and Interoperability in the EU (2018).

End