INVESTIGATING ON-CALL WORK IN RAIL INFRASTRUCTURE MAINTENANCE

NUNO MIGUEL FERNANDES CEBOLA, BSc, MSc.

Thesis submitted to the University of Nottingham

for the degree of Doctor of Philosophy

July 2014

ABSTRACT

The use of on-call work in industry has now surpassed that of shiftwork and night work. Industries as a whole make use of on-call work daily as a way to maintain 24/7 operations whilst also reducing costs. Despite this, on-call work remains under-researched and no best practice or management guidelines are available.

As the first substantial piece of human factors work examining on-call work in the rail industry, this thesis has the overall aim of increasing the understanding of on-call scheduling systems of work, and also to provide recommendations to the planning and management of on-call work in the rail industry which may also be applied in other industries.

A semi-structured interview study with 72 rail maintenance on-call workers of Great Britain rail infrastructure owner and operator (Network Rail) explored on-call arrangements in place and the perceived unwanted consequences of this type of work. Anxiety, fatigue, and reduced well-being were perceived as the main consequences of working on-call. The findings also indicate that when discussing on-call there are three separate on-call situations; being on-call, receiving calls, and responding to calls; which influence the study variables differently.

From the key themes identified initially an on-call questionnaire for managerial staff was developed and data from across the country generating 479 individual responses. A two-week diary study (one week on-call and the week after) with 26 participants aimed to collect real-time ratings. Results indicated that working on-call was perceived as a leading cause of stress, poor quality of sleep and fatigue. This is due to the inherent unpredictability of on-call work, which is the key differentiating factor between on-call work and other types of working-hours systems. Receiving and responding to calls were perceived as detrimental to general well-being both to workers and their families, fatigue, and performance.

The work performed for this thesis allowed the development of the first on-call specific framework that identifies not only the key factors at play but also the relationships between them. It presents a set of principles or theories that other researchers can use to guide future research and that industry professionals can use to deliver more human friendly on-call work management processes and procedures.

ACKNOWLEDGEMENTS

I would like firstly to thank my PhD supervisors, Doctor David Golightly and Professor John Wilson. David (Dave), who dedicated so much of his time to read each chapter of this thesis (several times over), for his guidance both to the structure and content of each chapter, and for his continual support I am immensely grateful. Dave‘s good humour and his sensible and calm approach has made PhD supervision look easy. More than this, Dave showed genuine interest in the topic of this thesis, as only a parent of a small child who wakes up through the night could have; which could be, in its own way, referred to as ‘on-call work’. To Professor John Wilson, who, after a long battle with cancer, sadly passed away early last year. All who knew John personally (and many who didn’t) will know that he was indeed one of the great minds of the world of Human Factors. What some might not know is that despite his immense knowledge, and notorious ‘thick skin’ John always tried his hardest not to intimidate those of us with less knowledge or experience. John’s ability to see the greater picture and to solve many seemingly insurmountable problems almost instantly, allowed this work to get off the ground. It was truly an honour to have worked with, and indeed to have met, John.

I would also like to thank Network Rail and in particular Theresa Clarke for giving me the opportunity to conduct this research. Also at Network Rail I would like to thank Mike Carey for providing some chatting breaks after around 6pm in Melton Street and for allowing this work to be part of my day to day work for most of last year. Thanks also to Emma Lowe and Fiona Kenvyn for all their support, knowledge, and guidance on the implementation of fatigue risk management in industry, which underpins the work conducted for this thesis. I would like to especially thank Kate Moncrieff for her surmounting good humour and laughs that kept me sane for most of the years of work that brought me here and for all her help in structuring the interview data discussed in Chapter 5. Her knowledge and ability to structure interview data was absolutely indispensable! To the remaining, current and alumni, members of Network Rail’s Ergonomics team I want to extend my gratitude for all the support, friendliness, knowledge, help, and so much more. I would like to name you all here but that would make for another section of the thesis! Thanks are also due to my fellow PhD students at Network Rail and Nottingham during these years, for their support and kind ears when a good ranting or complaining session was needed. In sum, I thank them for sharing my pain!

Thanks also to my examiners, Professor Sarah Sharples and Doctor Phillip Tucker for their time and effort in reviewing this thesis and for their constructive feedback. I am grateful for their thoughtful comments, their valuable suggestions and corrections to this work, which helped me to improve it in various aspects.

From the bottom of my heart I thank also my parents, Alcibiades and Maria do Carmo, who, for so many different reasons, were indispensable along the years and continue to be. ‘Do fundo do coração agradeço aos meus pais que sempre me ajudaram e suportaram em todos os aspectos da minha vida, tanto emocionalmente como financeiramente. Sem eles não teria certamente conseguido chegado aqui!’ I thank them for their support, for always believing in me and for supporting my life choices, not to mention the financial support through the years! I am also in gratitude to my Granddad, Agostinho Fernandes, for his continual support and work ethic that was both an inspiration and a reminder that no task is too big to tackle. ‘Agradeço ao meu avô pelo seu contínuo apoio e pela sua ética de trabalho que tanto me ajudou ao longo dos anos’. I also thank my sister, Ana Rita, my friends (too many to list here but you know who you are!), my extended family, and my dog, Pachorras, for providing support, friendship, distraction, and laughter that I needed (and many times when I potentially didn’t) across these four years. I am also in debt to my fellow tangueros and tangueras, who many times provided a much required distraction from work. Your good humour, laughter, and dance steps were able to neutralize even the most stressful of days! I am also in debt to Nicole Kirkham (parent-in-law to be) for proofreading the two longest chapters of this thesis without which, submission would have had to be postponed. Thank you!

Finally, last but not least, I thank my fiancée Justine Kirkham-Myers (soon to have a reduced surname) for her unconditional support, encouragement, emotional nourishment and love, the proofreading of most chapters, and pterodactyl cakes! Not to mention all of the other delicious dishes that fuelled me through many nights and weekends of work. Without whom this work would, undoubtedly, have been completed months, if not years, earlier! Admittedly with much reduced work-life balance.

Thank you all! This thesis is dedicated to all of you although I’m sure none of you will be in a huge rush to read it (again for some of you)!

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF TERMS

Asset Recovery Manager (ARM) – role in Infrastructure Maintenance responsible for resolving a fault and in effect responsible of restoring assets to their full operating capacity,

Delivery Unit (DU) – Section of the rail network,

***Distal* on-call –** On-call work when the worker is not required to remained in the work location whilst performing these duties (e.g. rail workers),

Electrification and Plant (E&P) - Function responsible for managing and maintaining the systems that provide electric power to the railways,

Fault Control - A 24/7 manned Network Rail department that monitors the track and reports and logs faults,

Frontline staff – Skilled manual rail workers that physically conduct work on the railway,

GB – Great Britain,

Infrastructure Maintenance - the department responsible for providing the day to day management and maintenance of the rail infrastructure, ensuring the safety of the track to run trains,

Infrastructure Maintenance Delivery Manager (IMDM) - Supervisory post within Infrastructure Maintenance responsible for the management of a Delivery Unit (DU),

Normal working hours – Regular working hours. These can involve office hours or shift work and these can be rotating or non rotating shifts,

Not on-call – The period of time when a worker is not performing on-call duties but is still working under his or hers normal working hours,

Off-track - Function responsible for dealing with the area surrounding the track such as fences or trees,

Permanent way (Pway) - Function responsible for the design, installation, and maintenance of the track and ancillary installations such as rails, sleepers, and ballast,

Possession - Disconnecting of a section of track form the network so that maintenance work or network upgrades can be conducted on that section,

Proximal **on-call** - On-call work when the worker is required to remain on the work place during their on-call duties (e.g. doctors),

Receiving callouts – The reception of a call to conduct work over the telephone (e.g. make a decision, provide advice),

Responding to callouts – The reception of call to conduct work that required attendance on site, i.e. requires travelling to a piece of track,

Section Manager – Supervisory posts within Infrastructure Maintenance responsible for the day to day maintenance of a section of the railway,

Signalling and Telecommunications (S&T) - Function responsible for the design, installation and maintenance of Signalling equipment and Telecommunication systems,

Stand-by – The period of time when one is working on-call but has not received callouts,

Supervisor or Assistant Section Manager – Supervisory posts responsible for the coordination of day to day maintenance work of a section of the railway,

Telecommunications (Telecoms) - Function responsible for the provision of telephone and data transmission facilities on the railway.

Chapter 1 – Introduction

On-call work is now the most common working hours scheduling system of work in Europe, ahead of both shiftwork and night work (Eurofound, 2012). Network Rail (NR) Infrastructure Maintenance is one of those departments that make use of this system. This sudden popularity of on-call work is, arguably, due to on-call being a cheaper option to shiftwork as it does not require 24/7 manning (Nicol & Botterill, 2004). Regardless of the reasons for its use it is imperative that the potential consequences of this type of working hours system are understood.

The programme of research described in his thesis was intended at its outset to explore the leading causes of fatigue in rail maintenance workers. It was during the initial stages of familiarisation with the rail industry and with Network Rail's current fatigue risk management system that the topic of on-call work emerged as an issue in need of clarification. Quickly it was identified that this working hours system of work was not well understood at Network Rail. Academia offered also little knowledge and the little research available focused mainly on medical interns whose on-call arrangements do not resemble those of the railways (e.g. Kiernan, Civetta, Bartus, & Walsh, 2006; Saxena & George, 2005; Wesnes et al., 1997).

The following thesis is therefore an investigation both in terms of practice, and to highlight some of the outcomes and underpinning mechanisms, of on-call work. While it has been conducted in one specific setting, rail maintenance, it is hoped the results can be extended to other relevant domains for what is an increasingly common form of work.

1.1 Background

Many of the 21st century industries, including the railways, rely on 24/7 manning to deal with the demands of our, increasingly, 24 hour society. To do so, industry has for many decades now relied on different working hours systems such as shiftwork, night work, and more recently on-call work. Potential unwanted consequences of such working hours systems were quickly recognised by both industry and academia. A large number of such health and safety consequences have now been identified. Shiftwork research for example has been linked to fatigue (Ǻkerstedt & Wright, 2009; Ǻkerstedt, 1998; Fletcher & Dawson, 2001), performance (Folkard & Tucker, 2003; Lockley et al., 2007), health (e.g. Geiger-brown, Muntaner, Lipscomb, &

Trinkoff, 2004; Harrington, 2001; Knutsson, 2003), and well-being (Haines III, Marchand, Rousseau, & Demers, 2008).

Contrary to shiftwork, on-call work has received very little attention both by industry and academia and little is known about the unwanted consequences it generates (Nicol & Botterill, 2004). The major difference between on-call work and shiftwork lies in the uncertainty and unpredictability of knowing when a callout will occur when working on-call. It is this inherent randomness of on-call work that clearly differentiates it from other work scheduling systems and allows for the assumption that its impacts on stress, quality and quantity of sleep, fatigue, and other factors known to be associated with shiftwork will have a unique impact in on-call work. Nonetheless, on-call work is now in effect in many industries affecting many occupations such as doctors, media personnel, pilots, rail personnel, and many others (Eurofound, 2012). This lack of understanding paired with the high prevalence of this working hours system of work steered the focus of this thesis to the investigation of this type of work.

Available on-call research has identified that on-call workers experience reduced sleep quantity and have poorer sleep quality. It has also been found that on-call workers have higher daytime sleepiness and take longer naps when compared to controls, experience higher levels of stress and anxiety, are more prone to suffer from depression, tension and frustration, and have higher intentions of turnover (Heponiemi et al., 2008; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988). Well-being focused research identified also that on-call workers suffer from lower well-being, and find it harder to maintain a healthy work-life balance (with the impacts of on-call extending to the workers' families as well) (Imbernon, Warret, Christine, Chastang, & Goldberg, 1993; Van Gelder & Kao, 2006). Performance may also be affected by on-call work with a study identifying that on-call medical interns have impaired cognitive performance and reduced mood (Wesnes et al., 1997). Another (also with medical interns), however, found no differences in performance, fatigue, and concentration resulting from on-call work (Kiernan et al., 2006).

In industry, on-call work is not regulated, being that at an European or Great Britain (GB) level. This is also the case at Network Rail where on-call does not have standardised management procedures. At NR, and most likely across industries, the on-call system of work was initially designed to ensure that in the event of emergencies during the periods between shifts there would be a number of qualified workers available to resolve any faults that might occur in the infrastructure. It was further designed to allow workers struggling to maintain the infrastructure or in resolving a fault to reach an expert and gain advice.

The local procedures in place do not regularly assess risk of fatigue or of high workload and on-call work is in effect, standardly scheduled together with shiftwork. What this means is that workers complete their daily work pattern and then perform on-call duties outside their working hours. Regardless of this lack of regulation, the Railways and Other Guided Transport Systems (ROGS) defines on-call work as "waiting to respond to an emergency callout or answering a query from people working in the field" and Network Rail's standard NR/L3/MTC/MG0224 goes even further and adds that "the time spent waiting is not considered as work" which effectively places the on-call scheduling system outside all working hours regulations. The definition presented in ROGS is, nonetheless, aligned with definitions used in other on-call research (e.g. Eurofound, 2012; Imbernon et al., 1993) and, as such, this shall be the definition of on-call work throughout this thesis.

1.2 Aims and Objectives

The overall aim of this thesis is to increase the understanding of on-call scheduling systems of work, and also to provide recommendations to the planning and management of on-call work in the rail industry. To achieve this, the work conducted for this thesis was conducted following five objectives:

- Identify and describe the on-call arrangements and management practices in place at Network Rail,

  Similarly to all other working hours scheduling systems on-call work is industry related. As such, Network Rail and the rail industry provide the context for the on-call scheduling systems and ultimately describe the on-call scheduling system of work under analysis for this thesis,

- Describe the perceived work, social, and personal consequences of working on-call,

  As the main areas of impact identified by on-call literature this thesis endeavours to further the knowledge into each of these areas. Furthering this knowledge will also benefit the Fatigue Risk Management System in place at Network Rail,

- Assess the relationships between the different factors at play in on-call work,

  Shiftwork research has identified that time of day, amount of time on task, extended wakefulness to mention but a few, are all factors that influence the intensity of unwanted consequences such as fatigue. It must be expected that similarly to other working hours scheduling systems, the negative outcomes of on-call work will also be influenced by many different factors. The identification of these and their relationships will be of great advantage to the understanding and management of on-call work,

- Develop an on-call specific framework where factors that are of importance are represented and so are the relationships between them,

  Following from objective 3 and in alignment with shiftwork research, a framework where all the factors of influence are identified together with the relationships between them will form a powerful management tool for industry and academia alike,

- Develop a set of research based guidelines on how to better manage the risks associated with on-call work,

  Through the identification of the main factors of influence of on-call work and of how these interact and lead to unwanted outcomes such as fatigue, a set of management guidelines can be produced. These will allow on-call management to be aligned with research findings in an attempt to reduce the negative outcomes of on-call work.

As stated before, on-call work remains the least explored domain of working hours research. This provided the justification for the descriptive and exploratory nature of these objectives. To achieve them a mix of qualitative and quantitative methods were used across this thesis. The research methods and how they provided the data required to address these objectives is discussed in detail in Chapter 4.

1.3 Key theoretical areas of interest

The key themes or theoretical areas of interest to this thesis (apart from on-call work itself) are aligned with working hours research (of which on-call work is a part of).

The key theoretical areas assessed through the work conducted for this thesis are:

- Fatigue Risk Management,

Network Rail, as the sponsor and main stakeholder of this research has a special interest in managing the risks associated with staff fatigue. As a result the work of this thesis originated in fatigue risk management related work, and fatigue, as a construct, remains a central key theme of this thesis (Chapter 2 describes this in greater detail).

- Callout specific factors,

Number, timing, and length of callouts together with on-call arrangements, such as length of on-call period and on-call roster rotation, are some of the key areas of interest of this research. On-call research lacks descriptive data regarding on-call arrangements and little research has investigated the impact of specific callout factors.

- Sleep research,

Sleep, and in particular sleep disruption, is another key area of interest for this thesis. On-call work inherently creates sleep disruption and sleep fragmentation as it involves the reception of callouts during the night. Circadian rhythms and the homeostatic sleep drive also fall into this area of interest.

- Well-being,

Another theoretical area of interest for this thesis is personal and inter-personal well-being. It can be expected that on-call work will not only have a direct effect on fatigue through sleep disruption but that on-call workers' family and social lives will also be affected. A telephone ring from a callout will not only wake up the worker themselves but also their partner, and the need to attend a fault on track will affect social and family events.

- Stress, performance, and mood,

All these constructs have been found to be affected by on-call work and other working hours systems, namely, shiftwork. Although not the main focus of this thesis, it is recognised that these are key themes associated with on-call work and as such these are also examined.

All these key themes or areas of interest both influence this thesis and are affected by the outcomes of it.

1.4 Structure of the thesis

The thesis starts by describing the rail context in which the work was conducted and how initial work led to the election of the on-call scheduling system of work as the research topic. Given the industrial context of this thesis it was considered necessary to provide a basic understanding of Network Rail's Infrastructure Maintenance beforehand. This is presented in Chapter 2 where the key regulations that must be considered when investigating on-call work both in the rail industry and in industries in general are also discussed.

This helps to frame both the available literature investigated (Chapter 3) and the research methods used for each of the three research studies conducted for this thesis: semi-structured interviews, questionnaire survey, and diary study (Chapter 4). Given the limited on-call literature, sleep disruption and shiftwork related literature were also explored. The chapter concludes by identifying the main research questions of the thesis and how these are addressed by each of the methods.

The results of the each of the three research studies are then presented:

- Chapter 5 detailing the findings of semi-structured interviews,

  This study aimed to provide understanding of on-call arrangements in place at Network Rail and the identification of perceived work, social, and personal consequences of working on-call

- Chapter 6 describing the findings of a questionnaire survey,

  This study aimed to explore the universality of the findings of Study 1 and attempted to quantify the perceived impact of on-call work

- Chapter 7 discussing the findings of an on-call diary study.

  This study explored the differences in anxiety, fatigue, and mood when on-call versus when not on-call and the perceived impact of callouts on sleep indicators and performance.

The thesis then concludes with Chapters 8 and 9 with the overall discussion of the findings of the thesis, the contribution to the field of working hours research, and with recommendations for future work.

Chapter 2 – Research context and the development of on-call work as a research topic

2.1 Chapter summary

The following chapter presents a broad overview of the main areas and functions of Network Rail's Maintenance organisation and a description of how initial work led to the identification of the on-call system of work as a research topic. Fatigue management was the initial focus of this research but through work conducted at Network Rail the topic of research evolved from fatigue management to the analysis of on-call work scheduling for Network Rail maintenance workers. This research was funded by Network Rail, the Great Britain rail infrastructure owner and operator, where the author was based for the duration of the project as a part of Network Rail's Ergonomics team. Therefore, this chapter also gives background on history and organisational context relevant to understanding the role of on-call work within Network Rail.

2.2 Introducing On-Call

Since the introduction of machine-based manufacturing in the 18th century, which kick-started the industrial revolution, technology has been evolving at a pace never seen before throughout human history. Never before have technological advancements caused such a rapid change in the way the world is defined and operated. The appearance of the computer in the 20th century caused an even greater increase in the pace of how industries and services operate. What is today taken for granted and regarded as basic living conditions for many of us is dependent on 24 hours-a-day operation. Of all the industries that allow our life to be the way it is today, most of them, if not all, require constant monitoring, such as the transportation industry, healthcare, communications, military, power, water, manufacturing, and so on. Many others are becoming more and more automated and in many cases reducing the number of personnel needed to monitor them but monitoring is needed nevertheless.

For this, we rely on working hours systems such as shiftwork, night work, and more recently on-call work, which is fast becoming the preferred working hours system. Both shiftwork and night work have been, and still are, very common ways to provide the 24h monitoring demanded by society. In recognition of this change in work practices research has been investigating the impacts of long working hours for many decades. A growing body of research has identified a number of consequences on the safety and on the health of those of us required to work under systems that require 24 hour monitoring and the safety of others (e.g. Dinges, Neri, & Rosekind, 1997; Van der Hulst, 2003). For example, working long hours has been linked to sleepiness (e.g. Åkerstedt, 1995), to fatigue (e.g. Friesen, Vidyarthi, Baron, & Katz, 2008; Williamson, Feyer, & Friswell, 1996), performance (e.g. Gillberg, Kecklund, Goransson, & Akerstedt, 2003; Van Dongen, Maislin, Mullington, & Dinges, 2003), and with several health problems (e.g. Kecklund, 2005; Van der Hulst, 2003). Vehicle accidents due to sleepiness and medical errors have also been associated with working long hours (e.g. Drake et al., 2010; Gaba & Howard, 2002; Golden & Wiens-tuers, 2006; Salminen, 2000).

On-call work is a relatively new form of providing 24 hour monitoring but quickly became a common form of scheduled work in many of today's industries with 20.2% of us in the European Union (EU) already working under one or another on-call system of work (Eurofound, 2012). On-call work is a cross-sector form of work that is used in a great variety of occupations including doctors, utility workers, ships engineers, media personnel, pilots and many others. However, it has received very little attention in research (Nicol & Botterill, 2004). Furthermore, for many of these occupations on-call working is not an option but a part of the job itself. The reason on-call coverage is the 21st century's already preferred scheduling system is that it allows highly trained professionals to be in contact in case of, and respond when required to, critical situations when the normal volume of work does not warrant full shift coverage, i.e. evenings and weekends. Although on-call work makes sense from a cost saving perspective it is not without potential costs to those that are required to work under this system and subsequently to the organisations that choose to use it. Furthermore, this is not a system of work restricted to one type of occupation and is in fact common to all types of work, even if more common for *high-skilled clerical* workers and *low-skilled manual* workers[1] as the latest European Working Conditions Survey shows. Table 2.1 shows further details.

1 Occupations as defined in (Eurofound, 2012) are high-skilled clerical: Legislators, senior officials and managers; professionals. Low-skilled clerical: technicians and associate professionals; clerks; service workers and shop and market sales workers. High-skilled manual: skilled agricultural and fishery workers; craft and related trades workers. Low-skilled manual: plant and machine operators and assemblers; elementary occupations; armed forces.

Table 2.1 - Results from 2010 European Working Conditions Survey (EWCS) question Q37: "Does your work include on-call time?" (Eurofound, 2012)

		2010	
		%	N
GB	High-skilled clerical	20.8%	406
	Low-skilled clerical	11.2%	753
	High-skilled manual	14.7%	135
	Low-skilled manual	11.2%	251
	Total	14.5%	1545
EU 27	High-skilled clerical	23.1%	8116
	Low-skilled clerical	16.9%	15033
	High-skilled manual	20.5%	5111
	Low-skilled manual	23.8%	6717
	Total	20.2%	34977

In the healthcare industry most (if not all) doctors must go through a period of on-call work in their early professional development, which might go some way to explain why this sector is the only one that has shown an interest in researching this system of work. On-call research conducted outside the medical professions is scarce with only a few studies having been conducted. For example only a few studies have been conducted in the transportation industries (Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988) and one with gas and electricity workers (Imbernon et al., 1993). The limited on-call focused research available in academia will be discussed in more detail in the next chapter.

These are interesting findings as on-call work seems more common in transportation (30%), followed by the construction industry (27%), public administration and defence (24%), health (25%) and agriculture (23%). It also appears that almost a quarter of men (23%) work on-call whilst only 16% of women do (Eurofound, 2012). Moreover, although on-call work has only recently appeared as a topic of interest it is already as common, if not more common, than other working time systems such as shiftwork and night work. Table 2.2 shows details of the prevalence of on-call work when compared to shiftwork and night work both in Europe and the GB since 1995.

Table 2.2 – Percentage of working hours in the EU27 & GB Results from the last four European Working Conditions Surveys (Eurofound, 2012; Paoli & Merllié, 2000; Parent-Thirion, Macías, Hurley, & Vermeylen, 2007).

		1995	*2000*	*2005*	*2010*
EU 27	**On-call**	-	-	-	***20.2%***
	Night work	20.6%	18.7%	19.4%	17.9%
	Shiftwork	12.7%	19.7%	17.2%	17.1%
GB	**On-call**	-	-	-	***14.5%***
	Night work	26.3%	20.2%	20.3%	20.7%
	Shiftwork	16.3%	23.2%	15.2%	17.4%

2.3 The Rail Industry in Great Britain

On-call is a common form of work, and the rail industry in GB is not an exception. Many of its workers have to perform duties under this scheduling system across the organisation. To understand the relevance of on-call to the railways it is necessary to first look at some of the historical and organisational background.

Previous to 1993 the GB railways were managed by a public entity; British Rail, which in the privatisation era of Margaret Thatcher's government was dismantled and privatised. The Railways Act of 1993 set out the privatisation where British Rail was divided into a series of companies. Railtrack became the owner of the rail infrastructure in 1994 and several other companies took the role of operating the trains; Train Operating Companies (TOCs), and Freight Operating Companies (FOCs). There were also created three regulators; the Office of Rail Regulation (ORR), the Rail Safety and Standard Board (RSSB), and Rail Accident Investigation Board (RAIB).

After a series of major accidents (e.g. Southall, 1997; Ladbroke Grove, 1999; and Hatfield, 2000), revealing poor management, Railtrack was replaced, in 2002, by

Network Rail, the current owner and manager of the infrastructure. This was more than a change of infrastructure management companies. While Railtrack was a private shareholder company, Network Rail is a company limited by guarantee. Instead of shareholders, it is composed of representatives of the public, members of the industry, and members of the Department for Transport. In addition, entities cooperating with Network Rail in the management and development of the network include representatives of passengers, engineering contractors, TOCs, FOCs, and governance, among others. These are Network Rail's stakeholders.

It is the ORR who regulate the railways and which aims to ensure the efficient management of the rail network whilst also ensuring health and safety objectives are met. The standards for safety across the whole industry are provided by RSSB and it is RAIB's role to conduct investigation into accidents. The Network License, granted by the Secretary of State for Transport (as per the Railways Act of 1993), bounds the activities of Network Rail and sets the standards and terms for the service Network Rail is required to provide to TOCs and FOCs.

As described, the GB rail industry is characterised by variety. This variety is present even with the regards to the infrastructure where the number of diverse rail infrastructure in track specifications and age vary greatly. This diversity presents an identically diverse range of engineering challenges regarding the reliability of the infrastructure. Two main causes for unreliability can be identified:

- The coexistence of modern rail infrastructure with older infrastructure (e.g. tunnels, bridges and other civil engineering) in operation for over a century,
- The technological diversity in operation in the same area, such as signalling systems (mechanical level frame, solid state, or digital interlocking operated by VDU) or electrification (overhead line or third rail).

The challenges in maintaining reliability of such a network currently take place in a context of high demand on the infrastructure. At the time of writing, the GB railways registered one of the fastest passenger transportation growths in Europe. Eurostat's March 2012 Railways transport analysis shows that in the seven year period between 2004 and 2010, the number of passenger-kilometres in GB has increased around 22%, against 13% in Germany and 16% in France, from 43.474 million to 55.831 million (EUROSTAT, 2012).

Infrastructure Maintenance is the department responsible for providing the day to day management and maintenance of the rail infrastructure, ensuring the safety of the track to run trains. The rail network is arranged in sections, each managed by a different maintenance Delivery Unit (DU). Each DU is then divided into a number of more manageable sections or depots. The current structure of Network Rail is divided into 40 DUs, each of them with several depots.

During the years of Railtrack all maintenance work was done by contractor companies that would be paid to perform specific jobs around the infrastructure. When Network Rail took over in 2002, it was decided that all maintenance work would once more be conducted by the company. This was achieved in 2004. As a result, whole infrastructure maintenance departments were acquired from the rail contractor companies, such as Carillion or Ames, and were integrated into the company. The complexity of what basically was aggregating separate companies to Network Rail, has led to a slow process of change and integration of contractor working practices with Network Rail ones. As a result many legacy practices are still common practice at Network Rail resulting in a large variety of work arrangements across the company. On-call work, as will be seen through the development of this research, is not immune to these and there are several different procedures in place across the different DUs.

Network Rail’s Infrastructure Maintenance is organised into five separate Operational Functions, each responsible for managing different parts of the infrastructure. These are, Permanent Way (Pway), Off-track, Electrification and Plant (E&P), Telecommunications (Telecoms), and Signals and Telecommunications (S&T). Table 2.3 summarises each Operational Function per area of work. Each Operational Function then breaks down to a myriad of more specific roles but these five functions represent the management structure and, as such, are sufficient to differentiate the different management arrangements as each function share the same principles, procedures, and objectives.

Table 2.3 - Operational Functions

Operational Function	Area of work
Permanent way (Pway)	Function responsible for the design, installation, and maintenance of the track and ancillary installations such as rails, sleepers, and ballast.
Off-track	Function responsible for dealing with the area surrounding the track such as fences or trees.
Telecommunications (Telecoms)	Function responsible for the provision of telephone and data transmission facilities on the railway.
Signalling and Telecommunications (S&T)	Function responsible for the design, installation and maintenance of Signalling equipment and Telecommunication systems.
Electrification and Plant (E&P)	Function responsible for managing and maintaining the systems that provide electric power to the railways.

Each depot has a mix of teams from the different Operational Functions as required by the infrastructure (e.g. areas without electrification will not have an E&P function). Each different function in a depot is managed by the responsible Engineer of that function (e.g. The Track Maintenance Engineer [TME]), and above each Operational Function sit Senior Engineering Managers who manage each DU. The DUs are managed by the Infrastructure Maintenance Delivery Manager (IMDM) and by his assistant, the Infrastructure Maintenance Engineer (IME). At the other end sit Section Managers (SM) and their Assistants (ASM) who are responsible for managing a particular section of the track of each depot for each function. Figure 2.1 shows a template Infrastructure Maintenance organisational chart.

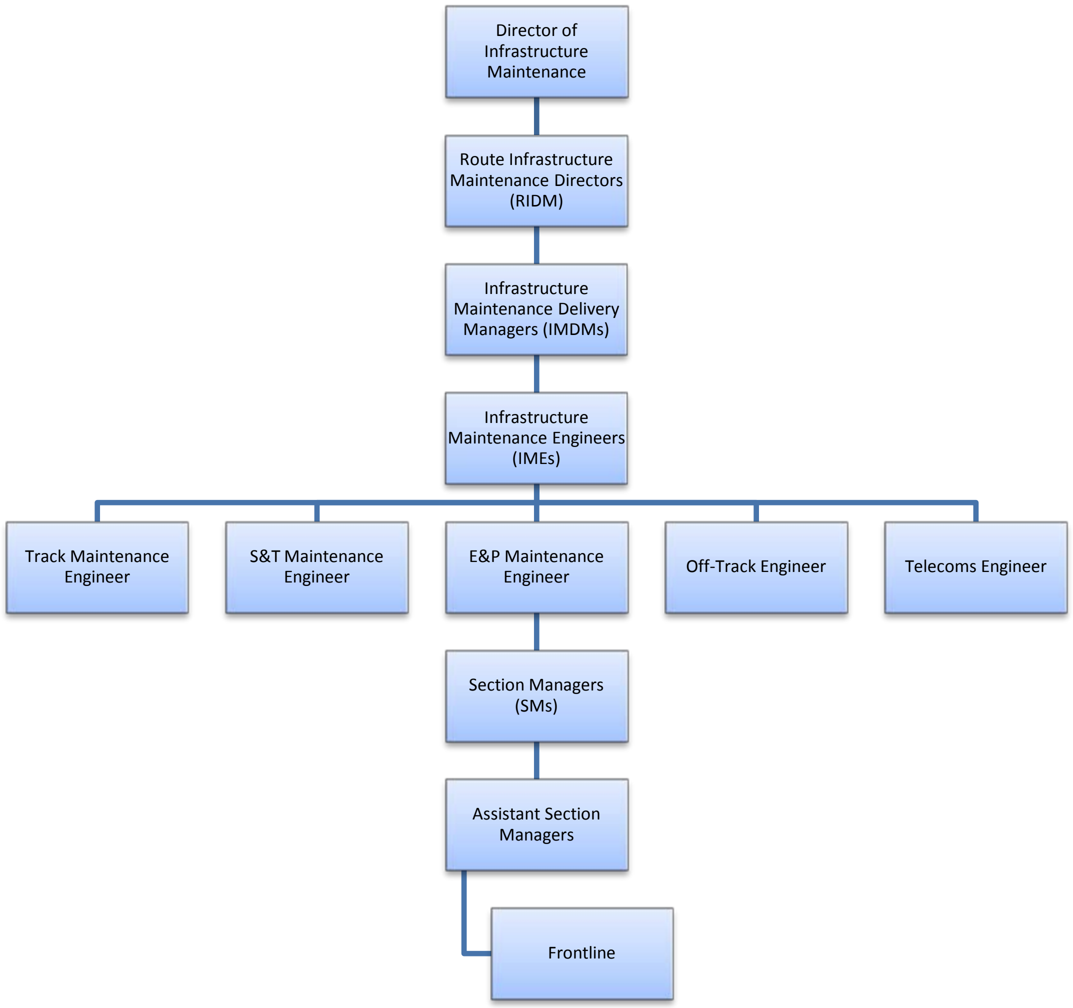


Figure 2.1 - Infrastructure maintenance organisational chart

On-call work at infrastructure maintenance might involve:

- Investigating issues reported by drivers (e.g. animal on track, person on track, open access gate to track),
- Emergency repairs to track or other rail infrastructure (e.g. level crossings, signals).
- Decision making for on-going works and emergency repair work (some decisions can only be taken by senior staff),
- Provision of expert advice for on-going work or emergency repair work.

On-call is, therefore, important to Network Rail as a whole and of particular relevance to infrastructure maintenance because:

- For many positions, the volume of work at night does not warrant full shift coverage,
- It is cheaper that 24 hour shift coverage,
- Staffed by highly trained professionals,
- Allows decision makers to make the decisions when they are required.

2.4 The identification of on-call as a research topic

Despite the business benefits and prevalence of on-call work at Network Rail, little is known about its operation or its impact on workers, reflecting the more general lack of research in the area. Initial work was conducted by the researcher on three projects relating to fatigue management at Network Rail. In each of these three projects, on-call arose as an area of concern, which led to the emergence of on-call work as an issue in need of clarification both at Network Rail and in the research literature.

2.4.1 Review of the Management of Fatigue and Working Hours Standard NR/L2/ERG/003

Participation on this project was one of the main driving factors that shaped the direction of the research topic to be investigated. The researcher was involved as part of the three people team tasked with reviewing and updating the standard. The main tasks performed by the researcher for this work were review of available up to date relevant literature, data analysis, and participation in steering and working group meetings to conduct and review the work. The ideas and concerns discussed below result from this process and were collected in the format of notes from the meetings and research work conducted to support the review.

During the fifth review of Network Rail's 'Management of fatigue and working hours for staff undertaking safety critical work' on-call work was one of the issues identified as problematic by senior managers involved in the steering group. It was felt that on-call work at NR was surrounded by a lack of clarity and knowledge regarding management processes.

The review took place between March 2010 and July 2011 and during the steering group meetings it became clear that on-call work is managed locally instead of centrally, and as such, there are no standardised management procedures. Senior managers felt it was not uncommon for lower level managers to be awakened several times during the night to respond to callouts. It was also felt that this type of work, many times, still required ‘normal’ shift hours to be maintained. An unwritten, cultural directive seems to be present which instigates managers to perform this way. It was mentioned more than once that it is embarrassing and damaging to their positions as leaders to either have a late start or to not be informed upon the beginning of their work day about what had happened during the night.

Formally, Network Rail is against this procedure (maintain *normal* working hours by not having enough rest) but informally the railway has a history of admiring those that are always available and that go the *extra mile*. This is still seen today even at the highest level of the organisation, for example, Ian Coucher (Network Rail’s CEO at the time this work was conducted) on the efforts to maintain trains running during the snow season in January 2010, praised the “dedication, commitment and determination of Network Rail people to keep the railway running” (Coucher, 2010).

2.4.2 Safety behaviour analysis at Clapham Delivery Unit

A request was made to the Ergonomics team to conduct research into the safety behaviour of the members of the Clapham Delivery Unit. The project required observations and interviews to be conducted with maintenance workers during their shifts and covered all three Clapham depots (Clapham, Wimbledon, and Feltham). All the management positions below Infrastructure Maintenance Engineer (IME) were part of the scope and interviews were conducted with members of all positions from all functions. See Figure 2.1 for details.

The topic of on-call, although not being a topic of interest during the work conducted on safety behaviour at Clapham Delivery Unit, kept surfacing as an issue. This was the case during the data collection phase of the project, and arose solely from frontline staff. Frontline staff are members of staff that are tasked to perform the physical work required to maintain the railways. In this case, all frontline staff interviewed belonged to the Pway. At this point in time, on-call work was also being identified as a topic of concern by the steering group involved in the review of Network Rail’s ‘Management of fatigue and working hours for staff undertaking safety critical work’ discussed previously. This was recognised and when mentioned, the issue was noted down by the researcher. At this time, on-call work was not yet a topic of interest to either the researcher or the piece of work underway at the time regarding safety behaviours, hence, no on-call specific data was collected.

The ideas expressed below represent the ideas mentioned by interviewees regarding the on-call system of work that the researcher noted down as interesting points. It appeared to the researcher that the frontline maintenance workers interviewed were content with performing on-call duties and saw it as part of the job they applied for. Attitudes were positive, with frontline staff being relatively happy with on-call work mainly due to extra payment (around £100 a week for being on-call plus overtime when called out). Despite this there were concerns regarding the management of on-call work with a number of members of staff feeling worried about the amount of on-call work assigned to them. Further concerns were raised regarding the amount of hours worked and the ensuing fatigue with workers feeling that the system in place had the potential to lead to an increase in their fatigue and stress levels. During this project there was no mentioning of on-call work by the managerial staff interviewed. However, as will be seen in the first research study conducted specifically for this thesis, managerial level workers are highly affected by on-call work.

2.4.3 Maintenance working hours audits.

To assess the management processes and monitoring of working hours at Network Rail Infrastructure Maintenance, Network Rail's audit team, in partnership with the Ergonomics team, developed and conducted an audit protocol for Network Rail's Infrastructure Maintenance. On-call work as a topic of interest in the management of working hours was by now emerging and on-call specific questions were introduced into the audit.

The audits were conducted in September 2010 at three different DUs across the country by a Network Rail audit team. The researcher had the chance to partake in one of them. Participation in the remaining two was not possible due to attendance to a previously organised Network Rail two week training course. The results of the audits were, nonetheless, compiled both by the researcher and the audit team with many weaknesses having been found in the arrangements of on-call work.

Many legacy working hours arrangements were found to be in place, i.e. working hours arrangements that remained from the previous contractor companies and that do not abide by Network Rail standards. It was found that none of the DUs investigated routinely recorded or risk assessed time working on-call. Furthermore, staff were found to be expected to risk assess themselves and record their hours of work, but a formal risk assessment would not necessarily be filled in. It was also found that on-call work basically means exceeding the 12h working hours limit as on-call work is performed concurrently with other working hours, i.e. staff work their normal shift, and then work on-call outside normal working hours (16h to 06h). The audit also revealed that most exceedances recorded were due to on-call work.

On-call arrangements were found to interfere with workers' rest periods and, as such, the auditor hypothesised these 'could have a potentially high impact on an individual's fatigue risk'. In addition, it was noted by at least one Infrastructure Maintenance Delivery Manager (IMDM) that Signals and Telecommunications (S&T) Section Managers (SM) tend to be called-out the most. This, as we will see when discussing Study 1, is due to the role of Asset Recovery Manager (ARM) taken by the S&T manager on-call.

2.4.4 Summary

The work conducted by the researcher in these three projects conclusively identified on-call work as a topic of research worth pursuing. Not only that, this work also identified a number of issues regarding this type of work and the way it is implemented and managed at Network Rail. The key activities in these projects that led to this were:

- Participation in the steering and working group meetings as part of the review of the Management of Fatigue and Working Hours Standard (NR/L2/ERG/003) to conduct and review the work, where on-call work as mentioned by several participants,
- Interviews with maintenance frontline staff regarding safety behaviours (where on-call work was mentioned as a factor at play),
- Development and conduction of fatigue focused audits (where on-call work was also assessed).

The issues identified were many and varied from the lack of standardised management arrangements to a disregard for fatigue consideration and the inexistence of risk assessment for on-call work.

To fully understand how these issues and others have come into being a review of the relevant regulations is also required. Unfortunately at the time of writing no on-call specific regulations exist both at a GB or European level. There are, however, a number of regulations regarding working hours which, in theory, should also regulate on-call work. The next section will explore these regulations.

2.5 Regulations

When researching the on-call system of work there are a number of regulations that, although not describing and defining on-call work in particular, are of importance to this system. These regulations aim to set limits and provide management systems to deal with other types of working hours regulations, namely, shiftwork and night work. Furthermore, these regulations, aim to mitigate the consequences of these types of work and, as such, can, and were used, as the initial stepping stones to investigate the on-call system of work. These also allow for the identification of some the risks on-call workers could be incurring.

2.5.1 European working time directive 93/104/EC

The 2000 amendment to the 1993 European working time directive 93/104/EC focused on aspects of the organisation of working time to cover sectors and activities excluded from the initial directive. This directive sets the European standard to manage working hours workers in all industries, including rail. The directive states an adult worker shall be entitled to:

- An uninterrupted rest period of not less than 24 hours in each seven-day period,
- A rest period of not less than eleven consecutive hours in each 24-hour period during which he works for his employer,
- Night work which shall not exceed an average of eight hours for each 24 hours

And either;

(a) two uninterrupted rest periods each of not less than 24 hours in each 14-

day period during which he works for his employer, or

(b) one uninterrupted rest period of not less than 48 hours in each such 14-day period.

The directive does not mention on-call work and, therefore, by the letter of European law this type of work is not regulated. There is the possibility that on-call arrangements might be regulated by local laws in each country, which is not the case in the GB where ‘on-call work is not specifically regulated by law’ (Carley, 2006).

2.5.2 Managing Fatigue in safety critical work Railways and Other Guided Transport Systems (ROGS)

In GB there is specific regulation to manage the railway, the Railways and Other Guided Transport Systems (ROGS). In this document the definition of on-call in the railways is clarified - “on-call means waiting to respond to an emergency callout or answering a query from people working in the field”. ROGS, however, does not expand on management guidance or on the risks associated with this type of work. With regards to working time limits the Managing Fatigue in Rail Safety Critical part of ROGS only states that when “spare turns or unplanned on-call shifts have a start time that varies by more than 2 hours, or late notice is given of additional or altered duties. For example, a person is told at 10 am that they are requested to work an evening on-call shift. A rest period of less than 8 hours has occurred because of on-call or emergency working. Planned work, together with overtime and unplanned on-call work, builds up to a working week of 72 hours, or more than 240 hours over a 28 day period” (ORR, 2006).

Furthermore, regulation 25: Fatigue; simply advises that fatigue management should be reviewed and managed; “every controller of safety critical work shall have in place arrangements to ensure, so far as is reasonably practicable, that a safety critical worker under his management, supervision or control does not carry out safety critical work in circumstances where he is so fatigued or where he would be liable to become so fatigued that his health or safety or the health or safety of other persons on a transport system could be significantly affected”. Much the same as with the European working time directive, the lack of detail regarding the management of on-call work leaves a hole in the regulation of this type of work. In sum, on-call work, at present, is not subjected to any type of regulation in GB.

2.5.3 Hidden Limits

The commonly referred to, Hidden limits, are derived directly from Lord Hidden who conducted the investigation into the 1988 Clapham Junction train collision (Hidden, 1989). In his report Lord Hidden identified fatigue as one of the leading factors of the accident. His recommendations effectively created the first set of working hours limits for the GB rail industry with the purpose of mitigating fatigue. These are:

- No less than 12 hours rest to be taken between shifts,
- No more than 13 days to be worked consecutively without a rest,
- No shifts to be longer than 12 hours,
- No more than 72 hours to be worked per calendar week.

It is generally accepted that these limits were not based on fatigue research and that they represent what was thought achievable for British Rail at the time. These limits existed in the industry since then and, at the time of writing, Network Rail was the only GB railway company that still refers to and uses these limits as part of its fatigue risk management system. Although not referring directly to on-call work, these limits represent the general limits that Network Rail should operate under. As we will see below this is not the case where on-call work is concerned as this type of work is not actively regulated and has, in effect, been allow to develop outside of regulation.

2.5.4 Management of Fatigue and Working Hours Standard NRG/L2/ERG/003

The fifth review of Network Rail's 'Management of fatigue and working hours for staff undertaking safety critical work' standard - NRG/L2/ERG/003 - was conducted during the year of 2011 and implemented in early 2012. Safety critical work can be defined as "work which has the most potential to lead to significant adverse effect on the safe operation of the railway system." (ORR, 2006).

The standard iterates and makes use of the Hidden limits but goes on to expand on the other characteristics of the Fatigue Management System in place at Network Rail, such as the use of a rostering fatigue assessment tool; the Health and Safety's Executive Fatigue Risk Index (FRI), and the use of exceedances (when breaching any of the set limits), forms and procedures. A roster is a plan of the turns of duty or leave for individuals or groups in an organisation, and is usually used to plan shiftwork. In this latest review of the standard the acceptable working hours limits at the company are modified to:

- No more than 12 hours to be worked per period of duty/shift,
- No more than 72 hours to be worked in any seven day period,
- A minimum of 12 hours rest between booking off from a period of duty/shift to booking on for the next period of duty/shift,
- No more than 13 periods of duty to be worked in any 14 day period.

The standard also states these limits are, on their own, not sufficient to control all of the risks resulting from the different working hours systems in place at the company. They form part of a set of working hours management arrangements in conjunction with other measures such as the risk assessment of base rosters and of actual hours worked.

The author was involved in the process of reviewing the standard and, as discussed previously, this work led directly to the development of on-call work as the topic of research. The lack of available research based knowledge meant that at the time of this review on-call work management guidance was not included in the updated revision of the standard. On-call work was, nonetheless, recognised as a risk and, as such, was included in the standard. On-call work was defined as stated in ROGS (see previous section). The standard mandates that on-call work must be monitored on a period basis including time spent responding to callouts both via telephone and in person. The standard further states that where there is a high level of callout activity identified over a prolonged period which regularly affects the ability of employees to obtain sufficient rest between duties, consideration should be given to reviewing the on-call arrangements for that location.

2.5.5. The 1999 Management of Health and Safety at Work Regulation

Regulation 3, risk assessment; of the Management of Health and Safety at Work Regulation mandates employers to make suitable and sufficient assessment of risks to the health and safety of their employees. These include risks to which they are exposed whilst they are at work, and the risks to the health and safety of persons not in their employment arising out of, or in connection with the work conducted by them of the employers' undertaking. To comply with this regulation on-call work must always be risk assessed to ensure both the safety of on-call workers and of others.

The regulation further states that any assessment shall be reviewed by the employer if there is reason to suspect that it is no longer valid; or there has been a significant change in the matters to which it relates; and where as a result of any such review changes to an assessment are required, the employer shall make them. In practice, this means on-call work arrangements should be reviewed and modified when required.

Regulation 5, Health and safety arrangements; of the same regulation further requires every employer to have appropriate arrangements in place for the effective planning, organisation, control, monitoring and review of the preventive and protective measures. In sum, these regulations require employers to have a risk management system in place to afford the highest possible protection to workers, and which is reviewed and updated on a regular basis.

2.5.6 Process for the management of fatigue and control of working hours standard for employees undertaking safety critical work NR/L3/MTC/MG0224.

The latest review of NR's 'Process for the management of fatigue and control of working hours standard for employees undertaking safety critical work' standard defines "the requirements for managing fatigue and working hours for Infrastructure Maintenance employees, and those employed under contract by Infrastructure Maintenance, who undertake safety critical work". The standard further describes which roles are classified as safety critical roles in Infrastructure Maintenance, the tools to be used to create rosters (roster creator tool, a Network Rail designed tool to assist in the design of rosters) and assess their risk of fatigue (HSE FRI). In essence, NR/L3/MTC/MG0224 describes how fatigue managements procedures and protocols must be practically applied in Infrastructure Maintenance.

The 'management of fatigue and working hours for staff undertaking safety critical work NR/L2/ERG/003' is directly mentioned as one of the reference documents and, as such, on-call work is also mentioned and defined. The standard uses the shared definition of ROGS and NR/L2/ERG/003: "On-call means waiting to respond to an emergency callout or answering a query from persons working in the field", but adds that “the time spent waiting is not considered as work for the purpose of this standard. On-call is only considered as work when work is actually undertaken, such as when the individual is managing an incident or supplying information”.

It further defines the role of on-call managers as “the nominated person during out-of-hours or emergency situations who is responsible for controlling and authorising exceedances to the working time limit for staff when the relevant Line Manager is not available”.

Quintessentially, with regards to on-call work, the standard does little more than define some of the roles on-call managers are expected to perform whilst working on-call. Moreover, the standard does not expand on fatigue issues on-call work might carry or how these can be addressed or mitigated. Much the same as NR/L2/ERG/003, this standard was initially designed to address shiftwork issues and, as such, is unable to address on on-call work arrangements. This is mainly due to the lack of on-call specific data and information on the documents it refers to, i.e., 93/104/EC, ROGS, and NR/L2/ERG/003.

2.6 On-call work as a research topic

As described earlier, on-call work developed as the research topic of this thesis from the three pieces of work discussed and from the realisation that both industry and academia have yet to fully address this scheduling system. This chapter has demonstrated that on-call scheduling is:

- Prevalent across all industries,
- Now one of the most common types of work scheduling across Europe,
- Not actively managed in industry.

The work conducted at Network Rail regarding the review of NR/L2/ERG/003 allowed understanding of the high-level planning involved in the general management of working hours in the company, the pressures felt by managers to always be knowledgeable of the work being conducted, and how unaware senior managers are of the processes and procedures in place locally to manage this system of work. The work conducted regarding safety behaviours at Clapham DU allowed for the acquaintance with this type of work and how its management and procedures affect frontline workers directly. The audits conducted brought to light the pressures felt in depots to perform and for workers to be available for work when they should be resting. These pieces of work clearly identified that on-call work is managed locally and revealed some of the challenges managers face to provide the required 24h coverage to the railway. From the knowledge gathered both from regulations and research work conducted into on-call work it is highly likely that Network Rail is representative of many industries and organisation.

This chapter further showed that on-call work is not regulated, being at a European or GB level, and that at Network Rail there are several issues with the arrangements in place regarding on-call work. From the initial work conducted by the researcher it was identified that on-call work at Network Rail exhibits a lack of standardised management procedures. The local procedures in place do not regularly assess risk of fatigue or of high workload and on-call work is in effect, regularly scheduled together with shiftwork. This led to a large amount of disruption of on-call staff during their recovery time between shifts. This means on-call work regularly does not always conform with the European Directive and Network Rail's own standard NR/L2/ERG/003. However, ROGS defines on-call work as "waiting to respond to an emergency callout or answering a query from people working in the field" and Network Rail's standard NR/L3/MTC/MG0224 goes even further by adding that "the time spent waiting is not considered as work" which effectively places the on-call scheduling system outside current working hours regulations. The definition presented in ROGS is, nonetheless, aligned with definitions used in other on-call research (e.g. Eurofound, 2012; Imbernon et al., 1993) and, as such, this shall be the definition of on-call work throughout this thesis.

The on-call system of work could be performed independently of other types of work such as shiftwork but, at Network Rail, on-call work is performed together with the other systems of work, namely, with shiftwork. What this means is that workers complete their daily work pattern and then, perform on-call duties outside their working hours. In Network Rail, and most likely across industries, the on-call system of work was initially designed to ensure that in the event of emergencies during the periods between shifts there would be a number of qualified workers available to resolve any faults that might occur in the infrastructure. It was further designed to allow workers struggling to maintain the infrastructure or in resolving a fault to reach an expert and gain advice. As will be discussed in detail in Chapter 5 the system has changed significantly since its creation and many workers feel on-call is now the norm instead of emergency only. This further adds to the risks posed by on-call work and to the necessity of providing knowledge to industry and regulators to better manage this scheduling system. It is the overall objective of this thesis to do so.

The lack of awareness of on-call work and its only recent appearance in the radar of research (e.g. Eurofound only added on-call work to its survey in the 2012 version) has allowed on-call work to live and grow in industry unchecked. Furthermore, in Network Rail at least, it is apparent that a culture of admiring and rewarding those that *go the extra mile* is still granting this system an accepted status.

In sum, on-call work is a prevalent scheduling system across industries that has received remarkably little attention both in academia and industry. Nonetheless, it seems obvious that it is a system that presents a high level of risk if not managed properly. This is certainly the case in GB railways where regulations do not cover on-call work. In the specific case of Network Rail, on-call work lacks a standardised management system. It is a scheduling system commonly used in conjunction with shiftwork which greatly increases the risk of fatigue and workload for on-call workers and the risk of errors and accidents that can cause severe incidents. Due to the lack of regulation and the high percentage of workers now known to work under this system across Europe it is also safe to assume these risks are common across industries where on-call has been allowed to flourish in an unregulated environment. From all the issues identified at Network Rail, the lack of industry regulations across Europe, and the scarce academic research behind on-call work, it became clear that on-call work was a topic warranting attention both for academia and industry and, thus, was adopted as the topic of this thesis.

2.7 Chapter Conclusion

This chapter presented the regulations that must be considered when discussing the on-call system of work. Although none of them present specific guidelines on how this type of work should be managed, the regulations present general guidelines which on-call work arrangements must follow. The chapter further demonstrates how the deficiencies in the regulation regarding on-call work and how initial work conducted at Network Rail led to the evolution of on-call work as the topic of this research. Involvement with Network Rail work regarding safety behaviours, the review of Network Rail's working hours standard, and working hours audits all led to the emergence of on-call work as a topic worth pursuing.

Surprisingly, despite being such a common system of work on-call has received little research attention. This is in sharp contrast with research on other working hours systems, such as shiftwork and hours of work generally, which have and continue to receive a great deal of attention in research and practical guidelines (e.g. Knauth, 1996; Knauth & Hornberger, 2003; Rosekind et al., 1995; Spencer, Robertson, & Folkard, 2006). The next chapter will discuss in detail the available on-call specific literature and, due to its limitations, expand on research into other working hours scheduling systems, to derive potential on-call related factors and risks.

Chapter 3 – Working scheduling in literature

3.1 Chapter summary

The following chapter explores the key fields of knowledge and literature that support the research carried out for this thesis. On-call available literature and its outcomes are addressed first. The available on-call related research is, however, limited and literature into sleep disruption, one of the idiosyncratic characteristics of on-call work is also investigated together with general sleep research. Shiftwork, a much more researched type of working hours arrangement, is also explored due to its similarities to on-call work. This is done in an attempt to understand which factors might be relevant for on-call work both in regards to inputs and consequences of on-call work. The chapter concludes by proposing an initial on-call specific framework of on-call related factors based on existing knowledge from the literature, presenting a list of predictions derived from all the literature reviewed, and by compiling the main research questions for this thesis.

3.2 Background

The previous chapter discussed both the intricacies of the rail industry and the regulations that must be considered when investigating on-call work. The regulations available, both at GB and European levels, do not present specific guidelines on how to manage this type of work. Other types of working hours systems are, however, covered, i.e., shiftwork and night work, and many rules and regulations have been created over the years to address these types of working hours systems. These point the way for the regulation of on-call system of work and involvement with Network Rail work regarding the safety behaviours, the review of Network Rail's working hours standard, and working hours audits all led to the emergence of on-call work as a topic worth pursuing in this thesis.

3.3 On-call work

Although a distinction is not clearly identified in the literature regarding on-call work it is felt that in effect, two distinct on-call systems are discussed. The continuous interest shown towards on-call work in the healthcare industry has focused mainly on interns' on-call working arrangements. These are very specific arrangements that are not shared by other industries. For medical interns on-call is a period of time in which the interns remain in the hospital for the duration of their on-call period. This type of on-call work can be referred to as a *proximal on-call system* as the worker remains in the work place and as a result, on-call doctors rarely have a chance to sleep when on-call. For other industries, and even in the healthcare industry, there is also a different type of on-call system in place where workers are not at their workplace when on-call and are instead at home, or simply away from the workplace. This type of on-call work, which can be referred to as *distal on-call work*, represents a period of time in which a worker is home but may be consulted over the phone or called back to work to resolve an issue. This can happen at any time of day or night.

As mentioned before, the bulk of the published work has mainly focused on medical interns, and has, as such, focused on *proximal on-call work* (e.g. Kiernan, Civetta, Bartus, & Walsh, 2006; Saxena & George, 2005; Wesnes et al., 1997). The *distal* on-call work system in comparison, which is the most common system in use, by contrast, has received less attention (e.g. Imbernon et al., 1993; Pilcher & Coplens, 2000). A major review into the *distal on-call system of work* found that the majority of work into the on-call system has concentrated on two areas; health impacts of working on-call, and the effects this type of work has on performance (Nicol & Botterill, 2004).

Whilst many industries make use of on-call work there are important differences between *proximal on-call* and *distal on-call* that might produce different outcomes, impacts, and challenges. The difference between *proximal on-call* and *distal on-call* make generalisation of their findings limited and dangerous. As we will see in the following chapters, *distal on-call* is the only type of on-call work in use at Network Rail and, as a result, throughout this thesis this will be the system discussed (this chapter being the exception where both systems are considered). Nonetheless, when appropriate, this distinction will be used when assessing literature findings and when discussing the findings of this thesis.

3.3.1 Effects of on-call work

As mentioned before, research into on-call work (both *distal* and *proximal*) is very limited and is concentrated in the medical sector, i.e. junior doctors/interns (e.g. Kiernan et al., 2006; Saxena & George, 2005), nurses (e.g. Kenyon, Gluesing, White, Dunkel, & Burlingame, 2007; Trinkoff, Rong, Geiger-brown, Lipsvomb, & Lang, 2006), and organ transplant coordinators (Smithers, 1995).

The majority of this research has focused mainly on the areas of sleep and health with a smaller number of studies also investigating the impacts on performance. Results from these investigations found that when performing *proximal on-call* work the amount of sleep resident doctors get per night when on-call is on average shorter per night than when working under non on-call hours (Van Gelder & Kao, 2006). These results were found using actigraphs and the authors also found that there was a significant increase in napping times on post on-call days vs. non on-call days. Another study conducted with ship engineers using an electroencephalogram and electrocardiogram together with subjective sleepiness ratings assessed the effects of on-call duties on sleep. The researchers found that on-call workers reported both higher degrees of sleepiness during the day following an on-call period, and a decrease in sleep quality (Torsvall & Akerstedt, 1988). In addition, the authors also found that on-call workers suffered from anxiety that disrupted their sleep. It was suggested that this was due to apprehension or uneasiness from the prospect of being awakened by an alarm. Similar results were found for the *distal on-call* system where locomotive engineers in the USA railway were found to have reduced quality and quantity of sleep when working on-call and where workers reported having more difficulties falling and staying asleep when on-call (Pilcher & Coplens, 2000). These studies suggest that the simple fact of being on-call can have a clear and definite impact on both sleep quantity and quality.

As mentioned before, a major review was conducted in 2004 to assess the effects of *distal on-call* work on health factors (Nicol & Botterill, 2004). The authors identified a total of 16 papers published in the field up to the year 2000 and identified four separate health areas that research has focused on: stress, sleep, mental health, and personal safety. Stress, and anxiety in particular, were found to be higher when performing on-call work (Imbernon et al., 1993; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988), on-call workers were found to have more depressive symptoms, and higher levels of tension and frustration (Rankin, Serieys, & Elliott-Binns, 1987; Rout, Cooper, & Rout, 1996). Personal safety was assessed in a single study which found that doctors are also fearful of falling victim of violence when responding to a callout during the night (Cooper, Rout, & Faragher, 1989). The authors go on to conclude that on-call work poses a risk to health but that there are also many gaps in the literature for a definitive conclusion to be derived. For example, on the topic of health effects alone there is a whole range of issues that have been linked to other forms of working hours, such as, cardiovascular disease, reproductive problems, and gastrointestinal issues that on-call research must address.

On-call work was also found to have an impact on workers well-being on the small number of studies that assessed this impact. A research carried out with electrical and gas engineers in France found that on-call work had a direct impact on the well-being of workers and their family life (Imbernon et al., 1993). Other research investigating the impact of on-call work on physicians found that physicians that work on-call for more than 40 hours per month reported feeling more distressed and to have more turnover intentions than other physicians (Heponiemi et al., 2008). Similar results were also found in the 5th European working conditions survey where workers were found to be less likely to have a good work–life balance when most job and individual characteristics are controlled for (Eurofound, 2012).

A very limited number of further studies have investigated the impact of *proximal* on-call work on performance and mood in medical interns. These studies have found that on-call work is associated with declining mood and impaired cognitive performance (Saxena & George, 2005; Wesnes et al., 1997). On the other hand, another study investigating these same factors, also with medical interns, found no differences between interns' performance, fatigue and concentration post on-call period, and controls (Kiernan et al., 2006).

3.3.2 On-call research summary

The available research has found that when on-call, workers experience reduced sleep quantity and have poorer sleep quality. On-call workers have also been found to have higher daytime sleepiness and take longer naps when compared to controls. On-call workers also experience higher levels of stress and anxiety, are more prone to suffer from depression, tension and frustration, and have higher intentions of turnover. Further research conducted into the well-being of on-call workers has found that on-call workers suffer from lower well-being, find it harder to maintain a healthy work-life balance, with the impacts of on-call extending to the workers' family also. One performance-focused study regarding proximal on-call work further identified that on-call medical interns have impaired cognitive performance and reduced mood. Another, however, failed to replicate these findings and actually found no differences in performance, fatigue, and concentration resulting from on-call work.

From the review of the available literature it is clear that the amount of research conducted on the on-call scheduling system of work and its outcomes or impacts is very limited. It is not, as such, unreasonable to deduce that this scheduling system of work warrants further investigation. Descriptive data on the different types of on-call work and how these shifts are organised is also missing, i.e. data regarding how many on-call shifts a worker is required to do in a row, how these shifts interact with other working hours shifts (e.g. shiftwork), and so on. This makes understanding the data very difficult and makes generalisation of results even more difficult. In sum, on-call literature must become more descriptive and must explore the many factors that are present in on-call scheduling (e.g. number of on-call shifts, arrangement of these shifts), the consequences of on-call (e.g. fatigue, stress, well-being) and the relationships between these factors.

There is a necessity to further investigate both the *proximal* and *distal* on-call arrangements separately and their impacts on those required to work under this system. It is also necessary to further assess the differences between these two types of on-call arrangements to assess how similar or dissimilar their impacts are. This is especially urgent when we consider that on-call work is now as common, or even more common, than other much better researched working hours arrangements i.e. shiftwork and night work.

In an attempt to bridge the gaps found in on-call research, the next section of this chapter will analyse research work carried out into fields that directly relate to characteristics of on-call work, namely, sleep disruption, fatigue management, and shiftwork.

3.4 Sleep

Having identified that sleep is the key human biological function on-call work disrupts, it becomes imperative to understand the negative outcomes of disrupted sleep. More than this, as the next sections will further demonstrate, sleep is an essential part of the equation assessing the relationship between working hours scheduling systems and negative outcomes. The parameters of this thesis do not allow for a complete exposition of the available sleep theory research as it is exceedingly extensive, with research originating from such diverse areas as biology, medicine, psychology, to name but a few of the disciplines which take an interest in sleep. As such, this section will focus on providing a broad overview of sleep research focusing on areas that directly relate to on-call work.

Sleep can be defined as a reversible behaviour state of perceptual disengagement from the environment (Carskadon & Dement, 1994) and is essential for most organisms, if not all, as without sleep, life cannot continue for more than a few days. Studies with animals have identified that sleep is a biological necessity where severe sleep deprivation through maintenance of wakefulness results in death (Bryant, Trinder, & Curtis, 2004). Regardless, attempts to identify a biological function of sleep have yet to succeed. A number of studies now have identified that sleep is related with many biological systems including metabolism (Knutson, Spiegel, Penev, & Van Cauter, 2007), with a recent study postulating that the restorative function of sleep may be a consequence of the enhanced removal of potentially neurotoxic waste products that accumulate in the awake central nervous system (Xie et al., 2013).

A number of studies have identified that the average adult human requires between eight hours and eight hours and 30 minutes of sleep for optimal performance and alertness (e.g. Dinges et al., 1997; Van Dongen et al., 2003). Sleep loss occurs when individuals fail to meet this amount of hours of rest in one evening and the repetition of this pattern is called sleep debt.

3.4.1 Sleep phases

A normal sleep cycle consists of two separate and distinct sleep states, Rapid Eye Movement (REM) sleep and non-REM sleep (Kerkhof & Van Dongen, 2010; Pinel, 1992) with research indicating that the recovery effect of sleep on the brain occurs during REM sleep, and on the body during non-REM sleep (Kerkhof & Van Dongen, 2010). A full sleep cycle is approximately ninety minutes in length and consists of five stages where the first four stages are non-REM sleep and the fifth consists solely of REM sleep. In a normal sleep period non-REM sleep accounts for approximately 75% of the cycle (Kerkhof & Van Dongen, 2010; Pinel, 1992).

The sleep cycle initiates with stage one. Here sleep is relatively light and lasts between five and ten minutes. At this stage the brain transitions from alpha waves to theta waves and it is common for individuals to experience twitches and jerks. Stage two is also classified as a period of light sleep (although not as light as stage one), lasting around 20 minutes, where rapid brain wave activity occurs (referred to as sleep spindles). In stage two the body temperature begins to drop and heart rate slows down. Deep sleep occurs in stages three and four where theta waves, also referred to as deep sleep waves, emerge (e.g. Carskadon & Dement, 1994; Kerkhof & Van Dongen, 2010; Pinel, 1992). REM sleep is recognised by the rapid eye movements (REM) and by low voltage activities similar to those present in stage one. Most dreaming takes place during this stage and other physiological events occur, namely, irregular body temperature, breathing, heart rate, and blood pressure (e.g. Carskadon & Dement, 1994; Miyasite, Fukuda, & Inugami, 1989; Pinel, 1992).

Research has identified that it is important to complete the cyclic process of sleep to achieve restoration (e.g. Belenky et al., 2003; Dawson & Mcculloch, 2005). Insufficient sleep quantity, sleep quality, use of alcohol, drugs, or medication, together with noise and light disruption (such as when sleeping during the day) all interfere with the physiological structure of the sleep cycles resulting in impaired performance and alertness when awake (e.g. Akerstedt & Gillberg, 1990; Turner & Stone, 2004; Van Dongen, 2006).

3.4.2 Two process model of sleep: Circadian rhythms and the homeostatic sleep drive

Extensive research has identified that at least two key processes are involved in the maintenance of appropriate sleep levels. These are the body's circadian rhythms that influence sleep and the homeostatic process (e.g. Borbély, 1982; Costa, 2003; Kong, 2008). The sleep-wake cycle is a archetypal example of a behaviour that demonstrates a circadian rhythm as it shows the characteristic intervals of activity alternating with restfulness with a clear periodicity over approximately a 24-hour day-night cycle (Harrington, 2001; Kong, 2008; Kuhn, 2001). The homeostatic process on the other hand is the process by which sleepiness increases through wakefulness and dispels with sleep where a sleep deficit elicits an increase in the duration and intensity of sleep to compensate for this deficit, and by which excessive sleep reduces sleep propensity (e.g. Borbély, 1982; Van Dongen, 2006).

The impact circadian rhythms have on human alertness has long been recognised. The first research into the effects of desynchronisation and resynchronisation of human circadian rhythms dates as far back as the 1960's (Aschoff, 1969). Since then many other studies have investigated circadian rhythm and its influence on shiftwork (e.g. Akerstedt, 1988; Billiard & Dauvilliers, 2004; Comperatore & Krueger, 1990; Nesthus et al., 2001; Turek, 1986).

The circadian clock is the biological mechanism in charge of regulating the daily variations in several physiological processes such as body temperature, sleep/wakefulness, respiratory rate, and hormone release. The approximate duration of a circadian period is one day (24 hours) (Harrington, 2001; Kuhn, 2001) and it is the matching of the endogenous circadian rhythms with environmental cues such as sunlight (a process known as entrainment) which provides internal stability to the organism whilst also allowing it to interact with the environment (Kuhn, 2001). In effect, circadian rhythms are characterised by having both an endogenous and an exogenous component. The human circadian timing system is composed of a number of structures in the brain which together contribute to the synchronisation of both physiological and behaviour rhythms (Comperatore & Krueger, 1990). The exogenous component is composed of various environmental cues, usually referred to as *zeitgebers*[2], including temperature and eating/drinking patterns. The light/dark cycle is the most powerful cue to human entrainment and has a direct effect on the sleep-wake cycle (Kong, 2008; M. R. Smith, Cullnan, & Eastman, 2008).

Research has shown that sleep related disorders are caused by a mismatch between the sleep-wake pattern and circadian phase. This is because this mismatch affects sleep both through circadian influence (trying to sleep when our body clock says we should be awake) and homeostatic influence (the increasing desire to sleep due to prolonged wakefulness) (Åkerstedt, Kecklund, & Gillberg, 2007; Åkerstedt, 2006a; Kuhn, 2001). It is the sleep-wake circadian rhythm that, by controlling both alertness and sleep, leads to diminished ability and increased sleepiness during the early morning hours (between 0200 and 0500) and to a lesser extent during the afternoon between 1400 and 1700 (e.g. Akerstedt, 1988; Nesthus et al., 2001). It is well known both in industry and research that these are the times when performance is at its lowest, and sleepiness and the risk of accidents are at their maximum (e.g.

[2] From the German for "time giver" or "synchroniser"

McGuffog, Turner, & Stone, 2004; Spencer et al., 2006).

3.4.3 Sleep debt and wakefulness

The mismatch between the sleep-wake pattern and circadian phase, and the negative outcomes that arise from this have traditionally been associated with the construct of sleep debt. Sleep debt can be defined as the difference between the amount of a sleep an individual requires versus the actual amount of sleep it obtains (David Dinges et al., 1997). Much research has shown that sleep debt has a detrimental impact on a large number of performance related factors (e.g. Caldwell, Caldwell, & Schmidt, 2008; Sallinen et al., 2004). These include slow reaction times, short attention spans, problems with short-term memory, and decreased problem solving and decision-making abilities (e.g. Belenky et al., 2003; Rosekind, Gander, Connell, & Co, 2001; Sallinen et al., 2004). Other research has also further shown that reducing the amount of sleep that an individual usually requires by as little as two hours is sufficient to significantly decrease the individual's subsequent performance and alertness (e.g. Dinges et al., 1997; Neri et al., 2002; Van Dongen, 2006).

The cumulative sleep pressure is a key feature of sleep debt where continuous days of inadequate sleep lead to a chronic sleep debt or sleep loss. In individuals that operate under the normal daytime orientation of work and social activities, chronic sleep debt occurs as a consequence of extensive hours of voluntary wakefulness. In an effort to accomplish more tasks, these individuals sacrifice sleep for additional hours of wakefulness (Van Dongen, Rogers, & Dinges, 2003). In the work environment, working shifts or on-call also leads to the build-up of sleep debt, where much research has shown that chronic sleep loss or sleep debt has been shown to contribute to a number of health issues, such as obesity, diabetes, and high blood pressure (Giovanni Costa, 1996; Totterdell, Spelten, Smith, Barton, & Folkard, 1995).

Although sleep loss and the resulting sleep debt has long been linked to the build-up of fatigue, recent studies have identified that extended wakefulness of over 16 hours for a number of days must also be considered as a cause of sleepiness and performance decrements. In effect, the researchers concluded that sleep debt may be better understood as the result from excessive cumulative wakefulness which has neurobiological impacts (Dorrian, Baulk, & Dawson, 2011; Van Dongen, Maislin, et al., 2003). For example, in a laboratory study, 40 subjects were divided into two conditions. One group was kept awake for 28 hours, and the other group was asked to consume 10 to 15 grams of alcohol at intervals of 30 minutes. Result showed that after 17 hours of sustained wakefulness cognitive psychomotor performance decreased to a level equivalent to the performance impairment observed at a blood alcohol concentration of 0.05% (Dawson & Reid, 1997). Another study using the same protocol to test simulated driving ability found identical results. In a driving simulation it was found that wakefulness prolonged to 17 hours can produce decrements in the ability to maintain speed and road position as serious as that of a blood alcohol concentration of 0.05% (Arnedt, Wilde, Munt, & MacLean, 2001). Accumulated sleep loss or extended wakefulness, has also been linked to the occurrence of microsleeps which are uncontrollable sleep episodes that occur when sleep spontaneously intrudes into wakefulness (Caldwell et al., 2008; Signal, 2002).

Recovery from sleep debt can only be achieved through continuous sleep (e.g. Belenky et al., 2003; Totterdell et al., 1995) although it is also known that sleep debt is not paid back uniformly (meaning that sleep loss is not recovered through an hour-for-hour restitution) with some research suggesting that the recovery process does not follow a linear process (Dawson & Mcculloch, 2005; Van Dongen, Maislin, et al., 2003) and that it may in fact follow a circadian variation (Dawson & Mcculloch, 2005). The speed of recovery has also been shown to vary greatly and to be dependent on a large number of factors with individual factors and work related factors both playing strong roles in recovery (Belenky et al., 2003; Rosa & Colligan, 1988; Totterdell et al., 1995). Recovery from sleep loss will be discussed further when discussing fatigue in section 3.5.1 Sleep, Fatigue, and Performance.

3.4.4 Sleep Disruption

Sleep disruption is an event directly related to on-call work (where calls commonly disrupt sleep) and has been shown to have a negative impact on performance, mood, and sleepiness. It has been shown that periodic sleep disruption causing fragmented sleep directly affects psychomotor performance on a number of tasks including tasks involving short term memory, reaction time, and vigilance. It has been shown to lead to mood decrements and increased subjective and objective sleepiness (measured through the Multiple Sleep Latency Test [MSLT]) both at the time of disruption and for days after (e.g. Bonnet, 1985; Bonnet & Arand, 2003; Stepanski, Lamphere, Badia, Zorick, & Roth, 1984). Furthermore, it has been shown that differences in the degree of sleepiness relate more closely to the degree of sleep fragmentation than to the type of sleep disturbance (Bonnet & Arand, 2003).

3.4.4.1 Sleepiness

The relationship between sleep fragmentation and sleepiness has been extensively documented in research conducted into sleep disruption. A major review into the effects of sleep disruption was conducted in 2003 and it was found that 13 of the 14 studies identified in literature exploring the effects of sleep fragmentation on alertness found significant increases in objective sleepiness (measured through the Multiple Sleep Latency Test [MSLT]) on the day following sleep fragmentation. Moreover, the review also identified that a number of studies provide evidence that it is the disturbance of sleep continuity that is the responsible factor at play (Bonnet & Arand, 2003).

Sleep apnoea, a medical condition where individuals suffer from temporary stoppage of breathing during sleep for 10 or more seconds (Mcnamara, Grunstein, & Sullivan, 2006) has been linked to sleepiness due to sleep fragmentation by large body of research (e.g. Bennett, Barbour, Langford, Stradling, & Davies, 1999; Mcnamara et al., 2006; I. Smith & Shneerson, 1995). Not surprisingly, it has been found that sleep fragmentation is much more common in individuals who suffer from sleep apnoea or other fragmenting sleep disorders, such as periodic limb movements (Bonnet & Arand, 2003). For example, in a laboratory experiment using 11 young adults it was found that following a disruption in sleep subjects' response to the addition problems used to measure performance was identical to that seen after one night of total sleep loss. Subjects also rated themselves sleepier than on baseline with the level of increase in sleepiness being similar to that seen after periods of total sleep loss of 40 to 64 hours (Bonnet, 1985). Likewise, a study using 16 adult participants found that one night of sleep fragmentation resulted in significantly higher sleepiness during the next day (Martin, Engleman, Deary, & Douglas, 1996). Another study comparing 30 patients complaining of excessive daytime sleepiness, 15 patients complaining of insomnia, and 10 healthy volunteers found that that the total number of arousals was significantly correlated with sleepiness in the day following disruption ($r = 0.48$, $\rho < 0.001$). This led the researchers to conclude that the number and type of disruption plays a role in the level of next day sleepiness (Stepanski et al., 1984). More recently, however, on a review of the literature published up to the year 2000 the same researcher advances that research now has clearly demonstrated that it is not "the number of arousals that matter most; it is the degree to which episodes of consolidated sleep are not long enough that leads to increased sleepiness" (Stepanski, 2002, p 275).

3.4.4.2 Performance

Sleep fragmentation impacts on performance have been consistently found on a several tasks including tasks involving short-term memory, reaction time and vigilance. For example, a study was conducted with 11 anaesthesiologists using a driving simulator to assess vigilance. The test ran through a period of 22 nights, 11 were undisturbed nights and 11 where sleep was disrupted. A significant improvement of vigilance scores was found after undisturbed nights of sleep. However, no improvement was found following a disturbed night and the subject's performance was worse if their sleep had been disturbed in the first third of the night (Murray & Dodds, 2003). Another study testing patients who suffer from sleep apnoea found that one night of sleep fragmentation results in significant decreases in mental flexibility and sustained attention (Martin et al., 1996). In another study with 700 participants it was found that the fragmentation of sleep was negatively correlated with cognitive performance in older individuals (Lim et al., 2012). In effect, performance deterioration due to sleep fragmentation has been linked to a large number of performance deficits, i.e. longer reaction time, lapses in attention or concentration, lost information, errors of omission, and poor short term memory (Bonnet & Arand, 2003). In a study comparing individuals suffering from sleep fragmentation due to suffering from sleep apnoea it was found that psychomotor performance was affected at about the same level as normal controls who had blood alcohol levels of 0.08% (Powell et al., 1999). These results clearly demonstrate the impacts of sleep fragmentation on various measures of performance that in on-call workers could lead to severe safety implications.

Related research regarding sleep inertia and its effects on performance has consistently found that both sleep inertia and sleep loss led to performance impairments. Sleep inertia can be defined as the phenomenon of disorientation occurring immediately after awakening from sleep relative to pre-sleep status (Tassi & Muzet, 2000). In a major review on the field conducted in the year 2000, researchers conclude that sleep inertia has been associated with decreased performance in a broad range of tasks, including reaction times, steadiness and coordination, visual perception tasks, memory tasks, logical reasoning tasks, and several cognitive tasks (Tassi & Muzet, 2000). For example, in a laboratory-based study with 16 adults, sleep deprivation was simulated over two nights and results showed that sleep inertia (during the first hour after awaking) led to an increase in reaction times in a visual attention task (Miccoli, Versace, Koterle, & Cavallero, 2008). On a similar study with 50 young adult subjects it was found that the auditory response speed was impaired due to sleep inertia (Hofer-Tinguely et al., 2005). In another study 15 male participants were asked to complete two minutes of arithmetic as quickly and accurately as possible after being awoken, with cognitive task impairment being found up to one hour and 17 minutes after being awoken (Jewett et al., 1999).

In their major review conducted in the year 2000 into the effects of sleep inertia the researchers concluded that the sleep stage prior to wakening is the most critical factor that leads to sleep inertia (Tassi & Muzet, 2000). The highest inertia was found to occur when awaking from slow wave sleep[3] with awakening in stages one, two, and REM sleep producing intermediate inertia. Furthermore, they also found that sleep inertia can last from one minute to four hours but that in the absence of major sleep deprivation, it rarely exceeds 30 minutes. The authors also conclude that prior sleep deprivation usually enhances sleep inertia since it increases slow wave sleep, and that there is no direct evidence that sleep inertia exhibits a circadian rhythm (Tassi & Muzet, 2000). These are concerning results for on-call work as due to the nature of on-call work it can be predicted that major sleep deprivation will be present for many on-call workers, leading to increased sleep inertia and, as a result, to impaired performance.

3.4.4.3 Well-being

Research assessing the impact sleep disruption has on well-being has focused mainly on its effect on mood, and results have shown in virtually all studies conducted that mood was found to be more negative after sleep fragmentation (Bonnet & Arand, 2003). For instance, a study conducted with 12 medical house officers using the

[3] Slow wave sleep or deep sleep consists of stages three and four of sleep (Schultz, 2008) and slow wave sleep develops 20 to 30 minutes into sleep (Pinel, 1992).

Nowlis adjective check list to assess mood found that mood was significantly affected by sleep disruption with the mood of officers deteriorating after a night with disturbed sleep (Deary & Tait, 1987).

Sleep disorders are common in pregnancy and for parents during early infancy and, as a result, the majority of research conducted onto the impacts of sleep disruption on well-being have mainly focused on childbearing and infant care (Lee, 1998). One of the main findings constantly identified in this research is the negative association between sleep disturbance and psychological well-being, including clinical depression (e.g. Chu & Richdale, 2009; Goyal, Gay, & Lee, 2007, 2009; Sloan, 2008). In a study with 112 couples, researchers found that mothers who slept four hours or less between midnight and 6am and mothers who had a nap shorter than 60 minutes during the day had an increased risk for depression at three months postpartum. These findings were found to be independent of the infant's temperament (Goyal et al., 2009). Another study conducted with pregnant women found that sleep disruption caused by hormonal changes as a consequence of pregnancy compromises physical well-being and mental health (Sloan, 2008). Similar results were also found in a study with 46 mothers and 50 children with developmental disabilities where the mother's sleep disturbance was found to significantly predict poor maternal psychological well-being (Chu & Richdale, 2009).

3.4.5 Sleep research summary

Under normal conditions the circadian rhythms and sleep debt (the two process sleep model) interact to produce levels of alertness throughout the day and to allow consolidated sleep during the night. It is when normal conditions are not met that issues arise. On-call work, shiftwork, and night work all disrupt these processes and, as a result, lead to a state where the sleep-wake cycle is disturbed leading to oscillating and unstable sleepiness across the 24-hour circadian cycle. This in turn creates a significant sleep debt through extended wakefulness, which has been shown to lead to impaired cognitive psychomotor performance which is comparable to the performance impairment observed at a blood alcohol concentration of 0.05% (Dawson & Reid, 1997) and to impaired alertness even resulting in microsleeps (Caldwell et al., 2008; Signal, 2002). More than this, chronic sleep debt has also been linked to a number of health issues, such as obesity, diabetes, and high blood pressure (Giovanni Costa, 1996; Totterdell et al., 1995).

In their major review into the effects of sleep disruption Bonnet and Arand (2003) found that sleep disruption leads to consistently higher objective and subjective sleepiness on the day after the disruption. In addition, using the results of eight studies they showed that sleepiness has a logarithmic relationship with the rate of periodic fragmentation, where a higher rate of periodic fragmentation (up to 20 minutes) leads to higher objective sleepiness on the day after the fragmented sleep. Sleep fragmentation rate is the rate at which sleep is disturbed in minutes. These findings are put in perspective by further findings making it clear that it is the sleep stage and the degree to which sleep is consolidated that leads to increased sleepiness (Stepanski, 2002, p 275).

Sleep disruption has also been clearly linked with diminished performance on several tasks including tasks that involve short term memory, reaction time and vigilance (e.g. Bonnet & Arand, 2003; Martin et al., 1996; Murray & Dodds, 2003). This is most likely due to sleep inertia where a similar relationship has been found. Other research has shown that slow wave sleep develops 10 to 20 minutes into sleep (Pinel, 1992) which is in alignment with the results found by sleep fragmentation research, suggesting that a similar effect as the one seen regarding sleep inertia is seen with regards to sleep fragmentation. The results of these two fields of research in effect complement each other and demonstrate the effects that waking from deep sleep have on performance. Although the impacts of sleep disruption on well-being have received far less attention than the impacts on sleepiness or performance, mood has constantly been found to be affected by sleep disruption. Research conducted specifically with parents of infants has also pointed that depression and general physical and psychological well-being can also be affected by sleep disruption (e.g. Chu & Richdale, 2009; Goyal, Gay, & Lee, 2007, 2009; Sloan, 2008). It is not unreasonable to assume that these same impacts are probably present in on-call work, as sleep disruption due to receiving calls is an intrinsic part of on-call work. Furthermore, it can also be expected that these impacts would spread both to the social well-being of on-call workers and their families as there is also the potential for their partners to be awoken also.

In sum, based on this field of research it can be expected that on-call workers, when the workers’ sleep is disrupted, experience reduced performance in task involving short term memory, reaction time and vigilance. All of these are common tasks in rail maintenance. It can also be expected that on-call workers will have a degraded mood, and, due to sleep inertia, suffer from sleepiness both after being awoken and during the day following the sleep disruption. As this research has shown, disruptions occurring at a rate of around 20 minutes after sleep have a higher impact than other rates of periodic fragmentation most likely because this is the onset of slow wave sleep. With this finding in mind, to better understand and assess the impacts of sleep disruption on on-call workers it is of importance to collect details regarding when and with what frequency on-call workers receive callouts. This will allow researchers to assess the validity of these laboratory findings in real world on-call workers.

3.5 Fatigue

This section outlines fatigue-related literature covering subjective feelings of tiredness and performance impairments and their relationship with accidents. The section further explores the knowledge available regarding fatigue and the literature available regarding the process of recovery from a fatigued state. Stress, as another specific outcome of this process, is also defined and assessed. In sum, this section highlights the cyclic processes of fatigue, recovery, and stress, and concludes with the discussion of the relationship between on-call work and fatigue. The topic of fatigue has received such a great deal of attention in research that in the scope of this thesis it is not possible to provide a complete review of the available literature. This thesis will, therefore, focus solely on the most relevant topics.

Similarly to many other constructs in Human Factors, there is still to be achieved a consensus on the definition of fatigue. Many definitions have been put forward and from these, many different ways to look and measure the construct have been developed and used, but “not much systematic theorizing has happened yet” (Michielsen, Vries, Heck, Vijver, & Sijtsma, 2004, p. 39) and definitions of the construct are poorly described in most of the current fatigue studies . To add to the problem, the literature identifies many different types of fatigue, such as sensory fatigue, cognitive fatigue, mental fatigue, and physiological fatigue (e.g. Gawron, French, & Funke, 2001; Van der Hulst, Meijman, & Rothengatter, 2001).What is more, the overlap of fatigue with concepts of performance, sleepiness, cognition, physiology and emotion does not help the search for a clearer definition or fields of study (McDonald, 1989).

At the cognitive level, fatigue has been linked to decreased vigilance, slower reaction times, memory loss, decreased psychomotor coordination, reduced information processing and impaired decision making ability. This effect is more pronounced in tasks that are monotonous, that have long duration, that demand constant attention, and that have low predictability (Lyznicki, Doege, Davis, & Williams, 1998). Sharing this view, time-on-task has been proposed as better term to use for task related fatigue (Van der Hulst et al., 2001) versus that of cumulative fatigue, which has been defined as the accumulation of fatigue associated with working over successive days or weeks (Spencer et al., 2006).

In the public eye, fatigue and sleepiness are very frequently confused (Philip et al., 2005) and when studying both sleepiness and fatigue as different concepts it was found that sleepiness and fatigue revealed mostly similar results possibly due to subjects not being able to differentiate between both concepts (Richter, Marsalek, Glatz, & Gundel, 2005). In effect, the same *confusion* can also be seen in research literature where the lack of a widely accepted definition of fatigue is proof in itself (Ream & Richardson, 1996). In research literature the term fatigue is commonly used and is generally understood as the tiredness and sleepiness that results from insufficient sleep, extended number of waking hours and circadian rhythm desynchrony (Åkerstedt, 1995). Throughout this thesis the construct of fatigue will follow the one agreed in consensus by a large international group of scientists in which fatigue is defined as the state of drowsiness, sleepiness and tiredness mainly resulting from the performance of work duties (Akerstedt, 2000)

Despite that a lack of an agreed definition of fatigue is yet to be reached, the presence of tiredness and impairments on work performance are the key elements present in most conceptualisations of fatigue in work settings. More so, an agreement on at least some of the different factors responsible for generating a state of fatigue (e.g. circadian disruption, sleep length) seem to be emerging and it has been established that fatigue is a common phenomenon for all workers independent of occupation and cultural differences (Leung, Chan, & He, 2004).

Traditionally, fatigue has been regarded as a condition associated with the amount of time spent on a given task (McDonald, 1989), but it has been shown that fatigue relates to other factors, such as, duration and quality of sleep, shiftwork and work schedules, circadian rhythms, and time of day (Hall, Francis II, Hammerschimidt, Goglia, & Black, 1999). In the aforementioned consensus statement regarding fatigue in transport operations compiled by Åkerstedt in 2000, it is also agreed that "the major causes of fatigue are: (a) the time of day of the transport operation (e.g. night/early morning), (b) a long duration of wakefulness, (c) inadequate sleep, (d) pathological sleepiness (sleep apnoea, etc.), (e) prolonged work hours (not necessarily operating the vehicle)" (Akerstedt, 2000, p. 395).

3.5.1 Sleep, Fatigue, and Performance

The impact of inadequate sleep and sleep loss on fatigue have been extensively studied and for many years it has been the focus of most studies that attempt to characterise fatigue (e.g. Akerstedt & Wright, 2009; Dawson & Mcculloch, 2005; Dinges et al., 1997; Samuels, 2001). Sleep loss can be defined as the amount of sleep one loses in one night, and sleep debt is the accumulation of that sleep loss during a period of work between days off.

In a cross sectional study with 5720 healthy employed men and women living in the greater Stockholm area a very strong correlation between sleep disturbances and fatigue was found (r = 0.84) with disturbed sleep being a predictor of fatigue. This led the researchers to conclude that disturbed sleep must be considered in the aetiology of mental fatigue (Åkerstedt et al., 2004). Other studies have found that impaired sleep not only plays a role in the development of fatigue but that it is also a factor in the development of exhaustion and burnout (Ekstedt et al., 2006; Ekstedt, Söderström, & Akerstedt, 2009). Although sleep loss has long been linked to the build-up of fatigue, recent studies have identified that extended wakefulness of over 16 hours for a number of days must also be considered as a cause of sleepiness and performance decrements. In effect, the researchers concluded that sleep debt may be better understood as the result from excessive cumulative wakefulness which has neurobiological impacts (Van Dongen et al., 2003). In another laboratory study 40 subjects were divided into two conditions. One group was kept awake for 28 hours, and the other group was asked to consume 10 to 15 grams of alcohol at intervals of 30 minutes. Result showed that after 17 hours of sustained wakefulness cognitive psychomotor performance decreased to a level equivalent to the performance impairment observed at a blood alcohol concentration of 0.05% (Dawson & Reid, 1997). Another study using the same protocol to test simulated driving ability found identical results. In a driving simulation it was found that wakefulness prolonged to 17 hours can produce decrements in the ability to maintain speed and road position as serious as that of a blood alcohol concentration of 0.05% (Arnedt et al., 2001).

When assessing the impact sleep loss has on sleepiness and fatigue, sleep quantity has been traditionally the chosen measure (David Dinges et al., 1997; Hall et al., 1999). Research into sleep quantity has indicated that the ideal number of hours of sleep for restoration to be achieved for an adult is around eight hours to eight and a half hours (e.g. Dinges et al., 1997; Spencer et al., 2006; Van Dongen et al., 2003). However, sleep quality has been identified as being as relevant or even more relevant regarding fatigue than the actual quantity of sleep (e.g. Dinges et al., 1997; Edéll-Gustafsson, 2002; Pilcher, Ginter, & Sadowsky, 1997; Rosekind, Gander, Connell, & Co, 2001) and has also been connected to health related issues, such as cardiovascular disease, anxiety and depression (e.g. Benca, William, Thisted, & Gillin, 1992; Hyyppa & Kronhollm, 1989). Sleep quantity by definition is easier to assess than sleep quality with number of awakenings at night, sleep latency, and sleep duration all having been used to measure sleep quantity in numerous studies. Sleep quality on the other hand has to rely on subjective ratings such as depth of sleep, easiness of arising, or how restful one feels upon awakening. Notwithstanding these limitations, two studies assessing the impact of quality and quantity of sleep in students found that sleep quality and sleep quantity account for approximately equal amounts of variance in sleepiness. Moreover, average sleep quality related better to health, satisfaction with life, and feelings of tension, depression, anger, fatigue, and confusion than average sleep quantity (Pilcher et al., 1997). A similar study conducted with 156 female shiftworkers found that reduced sleep quality in women is a cause of stress, of increased susceptibility to infection, moderate cognitive impairment, mood changes and somatic distress (Edéll-Gustafsson, 2002).

Sleep apnoea, one of the agreed causes of fatigue has also clearly been shown to have a direct relationship with sleepiness/fatigue through sleep fragmentation (Bennett et al., 1999; Mcnamara et al., 2006; I. Smith & Shneerson, 1995). The details of this relationship have already been discussed in section 3.4.4 Sleep Disruption, where sleep fragmentation is discussed in more detail.

In the laboratory a large number of studies have also linked fatigue with performance and identified a large number of performance impairments in vigilance and both cognitive and psychomotor ability, (e.g. Baker & Olson, 1994; Haire et al., 2012; Murray & Dodds, 2003; Van der Hulst et al., 2001). For example, when examining 13 healthy male volunteers' sleepiness during a vigilance task it was found that both subjective (the Karolinska Sleepiness Scale [KSS]) and objective sleepiness indicators (electroencephalographic [EEG] alpha activity) were closely correlated (r = 0.56) with performance on a vigilance task (Kaida, Akerstedt, Kecklund, Nilsson, & Axelsson, 2007). Since its creation the KSS has become one of the most popular fatigue self-measurement scales and has been used in several assessments of the relationship between fatigue and performance.

In another laboratory study, sleep restriction and its impact on performance was assessed with participants being put through one of three sleep doses (4h, 6h, or 8h) during 14 days with another group in a three day complete sleep restriction. The results indicate that sleep restriction to 6h or less during the duration of the study (7 days) resulted in cognitive performance deficits equivalent to two nights of total sleep deprivation. It was concluded that even relatively moderate sleep restriction can seriously impair waking neurobehavioral functions. Another very interesting finding was identified through subjective measures of sleepiness which showed that after a certain point subjects seemed to become unaware of their increasing cognitive deficits (Van Dongen, Maislin, et al., 2003). This effect has also been identified by other studies where these results led researchers to affirm that when attempting to judge how sleepy one individual is, that person is the worst person to ask (David Dinges et al., 1997). Additionally, fatigue has also been shown to have an impact on health with a recent study revealing a strong relationship between fatigue and gastrointestinal problems, cardiovascular disease, and musculoskeletal discomfort (Ku & Smith, 2010). Other research has also identified a relationship between fatigue and depression, anxiety, and forms of subjective stress and distress (e.g. Chen, 1986; G. Matthews & Desmond, 1998).

It has been suggested that the negative consequences of fatigue are due to a depletion of resources through the absence of recovery (Sonnentag & Zijlstra, 2006), and continuous sleep has been identified as the one way to recover from fatigue (e.g Akerstedt, Kecklund, Gillberg, Lowden, & Axelsson, 2000; Belenky et al., 2003; Nordin & Knutsson, 2001; Totterdell, Spelten, Smith, Barton, & Folkard, 1995). The speed of recovery from fatigue can, however, vary greatly and is dependent on a large number of factors. Early studies showed that two rest days are enough to return most psychological function to baseline values after a 60 hour week (Rosa & Colligan, 1988). However, more recent studies have found different results. In a study with shiftworking nurses it was found that one day off was not sufficient for recovery and that often three days were required (Totterdell et al., 1995). Another study in a laboratory setting assessed the recovery process following seven days of sleep restriction. Researchers found that three recovery nights were insufficient to allow performance to return to baseline levels. The amount of sleep was, however, restricted to 8h during the recovery days which may account for these findings (Belenky et al., 2003). A review on the literature published up to the year 2000 on recovery processes found that one day was never enough for recovery but two days were usually sufficient to provide recovery. The exception being circadian disruptions which were found to need up to four days to recover from (Åkerstedt et al., 2000). A more recent study has also found that shift schedules where the working week is 84 hours long require at least three days to recover from (Nordin & Knutsson, 2001).

In summary, the findings from recovery studies indicate that two days off between shifts with sufficient rest are usually a sufficient amount of time to allow fatigue levels to return to baseline values. The exception being long working weeks or shifts which disrupt the circadian rhythms, such as night shifts. It is, therefore, likely that on-call work, both through the reduction of recovery time and the disruption to circadian rhythms will also affect the rate of recovery. Furthermore, it has been shown that unscheduled overtime has a more disruptive effect and causes greater difficulties for the individual to organise sleep and, as such, recovery (Rosa, 1995). On-call work, due to its inherent uncertainty, may actually qualify as an extreme case of the disruption found by Rosa.

3.5.2 Stress and Fatigue

It is common knowledge that stress affects sleep. However, the mechanism behind this effect, although straightforward, may not be as easily perceived. Stress causes an increase in physiological and psychological activation which counter-effects the main characteristic of sleep, the deactivation of both these systems. Although stress has been the subject of a very large body of research there is relatively little empirical knowledge available regarding the relationship between sleep, fatigue and stress (Åkerstedt, 2006b). Nonetheless, this relationship exists and due to the potential on-call work has to cause a great deal of stress, namely, in the form of anxiety regarding the possibility of receiving callouts (Imbernon et al., 1993; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988). It is, therefore, an important construct for this thesis. Much the same as with the construct of fatigue, stress has received such a large amount of attention in research that it is not possible to discuss all the relevant research in the parameters of this thesis. As a result the following section provides a small exposition of the effects of sleep and stress as this is the one relevant relation for this thesis.

Although a common experience to all of us, attempting to define stress poses some serious difficulties. Stress research has predominantly followed either a physiological or a psychological strand (Mason, 1975). More recently these strands have became closer and in a review into the effects of stress in Air Traffic Control stress has been defined as the conjunction of both physiological and psychological effects where it is defined as an imbalance between demands and our ability to meet them resulting in a perturbation of the psycho-physical equilibrium, taxing physical, psychological and behavioural responses. It is when our ability to cope with this fails that stress can have a number of harmful consequences to our physical, mental and social well-being (Costa, 1995).

The effects of stress have been well researched with its effects being documented both at work and outside of work. In effect, stressful working conditions have been linked to a large number of health related factors, such as, hypertension (e.g. Costa, 1995; Rau, 2006), heart disease (e.g. Allesøe, Hundrup, Thomsen, & Osler, 2010; Tsutsumi, Kayaba, Kario, & Ishikawa, 2009), depression (e.g Melchior et al., 2007), reduced immune function (e.g. Boscolo, 2009), diabetes (e.g. Eriksson et al., 2008), and even to certain forms of cancer (e.g. Straif et al., 2007).

The relationship between fatigue and stress has been consistently reported both with life-event stress and work related stress (e.g. Akerstedt et al., 2004; Janssen & Nijhuis, 2004; Thorsteinsson & Brown, 2009). For example, to assess how different levels of stress influence sleep and fatigue the cortisol[4] levels of 34 blue collar and

[4] Cortisol or hydrocortisone is a hormone produced by the adrenal gland and has been shown to be released in response to stress.

white collar workers were measured during a high stress week and a lower stress week. The participants were also asked to keep a sleep diary and were rated for sleepiness. The level of stress in the evenings, measured through restlessness in bed, was found to be significantly higher during the stressful week which led to increased sleepiness through impaired sleep (Dahlgren, Kecklund, & Åkerstedt, 2005). In another study with 202 nurses the relationship between stress, fatigue, and personality factors was assessed. The researchers found a relationship between job stress and fatigue which was also dependent on personality factors such as negative affectivity (De Gucht & Guzman, 2004).

In a major review of the impact of psychosocial stress on sleep a large sample of cross-sectional studies was analysed with results showing that stress is associated with shortened sleep, sleep fragmentation, and a potential reduction of the deep sleep stages. Furthermore, it was also concluded that, although much research is still needed, shortened sleep may also exacerbate the effects of stress through the increase of stress markers such as cortisol (Åkerstedt, 2006b). These results identify a cyclical relationship between stress and sleep in which both constructs are intimately connected.

Although the relationship between stress and fatigue has been well established it is not clear how stressors exert their effects on fatigue but two recent studies have helped clarify this relationship. The first assessed 281 participants, both male and female, with ages between 18 and 70 years old, and the second assessed 609 participants with ages between 18 and 80 years old. The researchers found that a higher number of stressful life events led to higher levels of fatigue and that this relationship was mediated by low quality of sleep (Thorsteinsson & Brown, 2009). Although research has identified a relationship between self-rated stress and self-rated sleep quality (e.g. Doi, Minowa, & Tango, 2003; Edéll-Gustafsson, Kritz, & Bogren, 2002) these results went further in identifying a mediating role of sleep quality both for males and females (Thorsteinsson & Brown, 2009). Moreover a third study conducted by the same authors went further still and examined which features of stressors (e.g. frequency, duration, severity) relate more strongly to fatigue levels. After assessing 89 participants, higher fatigue levels were found to be strongly correlated with psychological distress, chronic difficulty stressors, and with the number of acute interpersonal stressors. Based on these findings the authors concluded that chronic stress frequency might be the best measure to assess the relationship between stress and fatigue (Brown & Thorsteinsson, 2009).

These results, identifying a relationship between stress and fatigue and the mediating effect of sleep quality in the relationship, are important results to the research of the impacts of on-call work. As a source of stress (Imbernon et al., 1993) it can be expected that on-call work will lead to reduced sleep quality and an increase in fatigue that will then lead to increased stress thus completing the cyclical relationship between stress, sleep, and fatigue.

3.6 Shiftwork

Given the obvious lack of knowledge in the field of on-call work, to be able to speculate on its relationship with other factors such as fatigue, performance, and sleep it is necessary to draw on research conducted into other working hours systems of work. Shiftwork represents the most commonly researched, and most relevant, working hours system to draw comparisons with

Shiftwork accounts for around 20% of all types of work schedules found in the workplace today both in Europe and across GB. Moreover, much the same as it is with on-call work and night work, this is true across occupations and industries (Eurofound, 2012). The 24 hour society is the drive behind the prevalence of such working hours systems and, in accordance to the needs of each business, shiftwork can vary greatly. Nonetheless, to cover the 24 hours of the day, shifts traditionally consist of either eight or 12 hours (Lawrence Smith, Folkard, Tucker, & Macdonald, 1998) which requires that workers adapt to the sleep-rest periods of their shifts. Although on-call and shiftwork are different working hours scheduling systems there are a number of similarities that can be drawn on to provide some insight into on-call work associated factors. Both systems are in common use, both can co-exist with normal working hours, both can lead to extended working hours, and both can operate outside normal circadian rhythms causing circadian disruption and sleep loss.

The major difference between on-call work and shiftwork lies in the uncertainty and unpredictability of knowing when a callout will occur when working on-call. It is this inherent randomness of on-call work that clearly differentiates it from other work scheduling systems and allows for the assumption that its impacts on stress, quality and quantity of sleep, fatigue, and other factors known to be associated with shiftwork will have a unique impact in on-call work. Nonetheless, the similarities between the two allow shiftwork knowledge to provide a basis for the analysis and development of on-call work in this thesis. As such, this chapter will now explore both shiftwork related factors and its known impacts on stress, fatigue, well-being, and health. However, the parameters of this thesis do not allow for a complete exposition of the available shiftwork research as it is very extensive. A short introduction of the more relevant factors for on-call work will, therefore, be focused on and presented here.

Shiftwork has been the target of much research for most of the second half of the 20th century. That research has identified a number of factors that are intrinsic to shiftwork. Of these, circadian rhythms and how different shift patterns subject shiftworkers to circadian disruption have been, together with sleep loss, some of the most researched shiftwork related factors. Later, and directly influenced by this research, arose also the study of how different individuals are more or less able to deal with the circadian disruption and sleep loss caused by shiftwork. This section will explore these main three factors that are present in and influence shiftwork.

3.6.1 Sleep loss / sleep debt

Based on a review on work conducted with regards to shiftwork in 1988, Ǻkerstedt stated that there is clear evidence that "shiftwork is associated with increased subjective, behavioural, and physiological sleepiness" (Akerstedt, 1988, p. 17). This was a statement that he reassessed and re-stated later in a review into the effects of shiftwork on sleep (Ǻkerstedt, 2005).

Sleep loss and sleep debt have both been linked to shiftwork, changes in the circadian rhythms and the difficulties of sleeping during day-time, but also to the diurnal orientation of social life (Ǻkerstedt & Wright, 2009; Balkin, Rupp, Picchioni, & Wesensten, 2008; Bonnet, 1985; Rupp, Wesensten, Bliese, & Balkin, 2009). As discussed before, shiftworkers' difficulty in sleeping during the day is most likely due to attempting to sleep at an inappropriate phase of the endogenous timing system (e.g Dawson & Mcculloch, 2005; Harma et al., 2002). As a result, research has shown that the typical day sleep of shiftworkers is between one to four hours shorter than normal night sleep (Folkard & Hill, 2002). Due to this, shiftworkers are at greater risk of suffering increased sleepiness and fatigue, and research has indeed consistently shown that these are prevalent issues during night time work (e.g. Akerstedt, 1998; Comperatore & Krueger, 1990; Harma et al., 2002; Sallinen et al., 2004; Van Dongen, 2006). Night work, in the circadian low point, and daytime sleep against the exogenous light regulator factor mean that shiftworkers have to both fight sleepiness in the night and wakefulness during the day. As a result these workers suffer from both sleep loss and from sleep debt as they are unable to get enough rest nor good quality rest during day sleep which can only be partly restored on their rest days (Åkerstedt, 1998). Shiftwork has been linked to a multitude of sleep disorders. For example, in a longitudinal study with more than 21000 people in France using a sleep disturbance index it was found that shiftwork is one of the main risk factors for the development of sleep disorders after controlling for age and gender (Ribet & Derriennic, 1999).

These issues occur partly due to the stability of circadian rhythms and the influence of both homeostatic and circadian influences that affect sleep. Shiftworkers can be said, therefore, to constantly be desynchronised, or off synchronisation with their circadian rhythms (Aschoff, 1969; Comperatore & Krueger, 1990; Giovanni Costa, 2003). Moreover, de-synchronisation has been associated with a number of health and well-being factors of which fatigue is most likely the more affected (e.g. Comperatore & Krueger, 1990; Costa, 2003; Sussman & Coplen, 2000). Furthermore, in a review of sleep related literature conducted in 2007 it was concluded that mental performance is also strongly influenced by many forms of displaced sleep (Åkerstedt, 2007).

3.6.2 Individual differences

Individual differences have been found to be present in most of the identified outcomes of shiftwork. Age is one of the most commonly mentioned factors with regards to shiftwork tolerance (e.g. Costa & Di Milia, 2008; Mikko Harma, 1996; Pires et al., 2009) with results showing that older workers can find it harder to work shifts. Gender differences have also been identified with women reporting a stronger impact of physical shiftwork (Costa & Sartori, 2007). Supporting this, other research has also identified that women tend to report higher levels of sleepiness whilst on-shift (Spurgeon, 2003).

The study of circadian rhythms is one of the most relevant aspects in the study of individual differences in shiftwork. These are the differences between different circadian typologies in the form of larks (morningness) and owls (eveningness). ‘Larks’ are people who naturally wake up early in the morning, and ‘owls’, are people who wake up and go to sleep late (Natale & Alzani, 2001; Phillips, 2009). Research has shown that extreme larks’ performance deteriorates throughout the day, while, in contrast, that of owls’ increases (Folkard & Hill, 2002). Not only this, recent research has found indications that larks circadian rhythms might reset faster after shiftwork than that of owls (Brown et al., 2008).

Research conducted with rostered air traffic controllers has found that owls have more flexible sleep habits and sleep significantly less than larks. Moreover, the same research found that, independently of the circadian typology, working the morning shift resulted in a reduced amount of sleep and that working the night shift resulted in decreased activity during the day (Natale & Martoni, 2003). Similar results were found by other researchers who found that shiftwork is linked to greater levels of drowsiness at night for larks and that owls report better daytime sleep quality (Smith et al., 2005).

Recently, a major review was conducted into the relationship between individual differences, such as age, gender, personality, morningness and eveningness, as well as biological variables, and different measures of shiftwork tolerance. The results of 60 studies conducted between 1998 and 2009 revealed that higher shiftwork tolerance is related to young age, male gender, low scores on morningness, high scores on flexibility, low scores on languidity, low scores on neuroticism, high scores on extraversion, and internal locus of control (Saksvik, Bjorvatn, Hetland, Sandal, & Pallesen, 2011). Moreover, other research has found that there are also a number of individual and organisational factors that contribute to mediate the health consequences of shiftwork. The organisation of rosters, the use of coping strategies, the psychological demands, and the amount of control over the work situation all mediate the health consequences of shiftworkers (e.g. Ku & Smith, 2010; Waage et al., 2009).

It is important to highlight that some studies have found that working shifts may not have a harmful effect on some individuals and that some individuals actually prefer to work shifts over other forms of work scheduling (Colligan & Rosa, 1990). Nonetheless, the overwhelming evidence suggests working outside what are considered *normal* working hours has a detrimental effect to the majority of workers (Costa, 1997).

3.6.3 Shiftwork negative outcomes

The adverse effects that come from shiftwork are well documented in literature and include fatigue (e.g. Ahsberg, Kecklund, Akerstedt, & Gamberale, 2000; Akerstedt & Wright, 2009; Baulk et al., 2007), stress (e.g. Costa, 2003; Milia, Bohle, Loudoun, & Pisarski, 2008; Sutherland & Cooper, 1996), performance (e.g. Della Rocco, Comperatore, Caldwell, & Cruz, 2000; Rollinson et al., 2003; Signal, 2002), well-being (e.g. Culpepper, Schwartz, & Thorpy, 2010; Jansen, van Amelsvoort, Kristensen, van den Brandt, & Kant, 2003; Tucker & Knowles, 2008), and health (e.g. Eriksen & Kecklund, 2007; Gold et al., 1992; Knutsson, 2003). Moreover, the extent to which we are affected by shiftwork has also been found to be dependent on the nature of the task (e.g. Folkard & Tucker, 2003), individual factors (e.g. Barton, Smith, Totterdell, Spelten, & Folkard, 1993; Sallinen & Kecklund, 2010), and both the organisational (e.g. Allan, Loudoun, & Peetz, 2007; Ku & Smith, 2010) and social environments (e.g. Pisarski, Bohle, & Callan, 1998).

In sum, the large body of research into shiftwork has associated a large number of negative outcomes with shiftwork. The next section explores the identified negative associations of shiftwork with fatigue, performance, and well-being in greater detail.

3.6.3.1 Shiftwork and fatigue

Of the many negative outcomes associated with shiftwork, fatigue is the main one and is seen as the mediator of many other factors identified as being impacted by shiftwork (e.g. performance, well-being). An association between shiftwork and fatigue has been consistently found in research, in particular with shift systems that are more disturbing to the circadian rhythms, i.e. night shifts and early starting shifts (e.g. Ahsberg et al., 2000; Akerstedt & Wright, 2009; Jansen et al., 2003). It is well documented that shiftworkers report having more sleep issues than day workers and that it is common for shiftworkers to also report feelings of fatigue (Ǻkerstedt & Wright, 2009; Ǻkerstedt, 1998; Fletcher & Dawson, 2001). In addition to the circadian disruption shiftworkers incur, shift length (12h versus 8h), shift rotation, and the speed of rotation, all have been identified as relevant causes of shiftwork related fatigue (e.g, Bendak, 2003; Pilcher, Lambert, & Huffcutt, 2000; Spencer et al., 2006).

In most industries, workers prefer to work 12 hour shifts as this allows for longer periods of recovery time, i.e. greater number of days off (e.g. Bendak, 2003; McGuffog, Turner, & Stone, 2004; Sallinen et al., 2004). However, the relationship between shift duration and fatigue has been identified by several studies (e.g. Lockley et al., 2007; Sallinen et al., 2003; Sallinen & Kecklund, 2010) and results seem to indicate that 12 hour shifts consistently reported higher levels of fatigue (Rogers, Spencer, & Stone, 1999). Further support for this was found by other research where time on task has also shown to have an impact on fatigue (Richter et al., 2005). Nonetheless, an extensive review into fatigue relating to eight hour versus 12 hour shifts found that shift duration had a highly significant impact on fatigue levels whilst also stating that these results were still largely equivocal (Smith et al., 1998). A second review assessing 49 studies across industries found further support for the larger impact of longer shifts but also conclude that the immense variation in the measures used and the constructs measured also make it hard to derive any conclusive results (Bendak, 2003).

Despite this, it is clear that shiftwork has a negative impact on fatigue. For example, in a large sample study in Sweden with more than 18000 cases, shiftwork was found to interfere with sleep and to be directly related to fatigue (Åkerstedt, Fredlund, Gillberg, & Jansson, 2002). Furthermore, the extensive research on shiftwork and fatigue has clearly shown that independently of the arrangements and mechanisms of shifts, and independently of individual variation, sleep loss and fatigue are major effects of shiftwork (Åkerstedt, 1990). More recently, in an extensive review of fatigue related literature it was stated that shiftwork has pronounced negative effects on sleep, subjective and physiological sleepiness, performance, accident risk, and health outcomes such as cardiovascular disease and certain forms of cancer (Åkerstedt & Wright, 2009).

The impact of working long hours on fatigue is also a well established phenomenon with much research having been conducted into the effects of long shifts and long rosters (e.g. Ahsberg et al., 2000; Akerstedt & Wright, 2009; Jansen et al., 2003; Smith et al., 1998). For example, in a large scale study conducted in the United States of America, the responses of 10793 individuals to an injury and illness longitudinal survey between 1987 and the year 2000 were analysed. It was found that working in jobs with overtime shifts was associated with a higher injury rate when compared to jobs without overtime (61% higher) and that working 12 hours or more per day or 60 hours or more per week was also associated with an increased hazard rate. Moreover, the researchers found that the injury rate increased in correspondence with the number of hours per day or per week of the workers' usual schedules. The researchers concluded that job schedules with long working hours are more at risk of injury not because these workers spend more hours at work, but due to fatigue or stress (Dembe, Erickson, Delbos, & Banks, 2005).

When fatigue increases so does the likelihood of human error, incidents and accidents. A large number of studies have, in effect, identified fatigue as a cause in accidents across industries. In the fatigue consensus statement previously described it is agreed that "fatigue (sleepiness, tiredness) is the largest identifiable and preventable cause of accidents in transport operations (between 15 and 20% of all accidents), surpassing that of alcohol or drug related incidents in all modes of transportation" (Akerstedt, 2000, p. 395). In the medical industry for example, fatigue has been identified as the third most common cause of medical mistakes (Wu, Folkman, Mcphee, & Lo, 2003). In another study, 3470 fatal and non-fatal accidents that occurred in textile manufacturing were analysed and fatigue was found to be a cause in the peak of accidents seen five to six hours after the beginning of the shift (Nag & Patel, 1998). On the same topic, research has also found that 10 hour shifts when compared to eight hour shifts have nearly a two-fold increase in the probability of the occurrence of incidents or accidents (Folkard & Tucker, 2003) and shifts that are 16 hours or longer were found to have a three-fold increase in accident probability (Rosa, 1995). Driving accidents, both professionally and commuting, have also been found to be associated with fatigue levels (e.g. Jay, Dawson, Ferguson, & Lamond, 2008; May & Baldwin, 2009; Morrow & Crum, 2004; Williamson, 2007; Williamson et al., 1996). For example, in a field study with 606 truck drivers, a significant correspondence between drivers' psychomotor performance and daytime sleepiness fatigue measures was found (Charlton & Baas, 2001). Another study using night work volunteers that regularly commute by driving used a driving simulator to investigate the effects of driving home from a night shift. The researchers found that when commuting home after the night shift versus when driving after a normal night's sleep drivers experienced increased subjective sleepiness that was associated with performance decrements. Namely, an increased number of incidents (two wheels outside the lane marking, from 2.4 to 7.6 times), decreased time to first accident, increased lateral deviation (from 18 to 43 cm), and increased eye closure duration (0.102 to 0.143 s).

3.6.3.2 Shiftwork and Performance

Major accidents tend to occur outside normal working hours and these accidents tend to be linked to mistakes made by workers who have been on shift for long periods of time. The relationship between shiftwork and performance has been extensively researched and there is a general consensus that accumulated sleep loss and sleep debt caused by shiftwork have consequences in performance (Marcil & Vencent, 2000). Shift length, much the same as discussed before with regards to fatigue, has been identified as one of the causes associated with decreases in performance (Lockley et al., 2007). A report on sustained operations compiled from sleep deprivation laboratory studies at NASA states that significant impairment can be seen in about a quarter to a third of personnel after 20h of sleep deprivation (David Dinges et al., 1997). As discussed when discussing the topic of fatigue, extended wakefulness appears to be the cause of these findings, even if the wakefulness is caused by shiftwork. For more in depth information of extended wakefulness refer to section 3.5.1 Sleep, Fatigue, and Performance. In addition, research has also identified that job performance is lowest and the risk of accidents is highest during most of the night shift, particularly around 0300 (Folkard & Hill, 2002; Spencer et al., 2006). As a result, both shiftwork and night work must be considered key risk factors as workers are exposed to an increased risk of accidents whilst at work (Folkard & Tucker, 2003).

It is generally accepted that performance during the night is impaired when compared to day time performance (e.g. Costa, 2003; Van Dongen & Dinges, 2000). Moreover, evidence also shows that both safety and productivity during the night are also affected (Folkard & Tucker, 2003). Comparison studies between day and night shifts have found that night shiftworkers, who had been awake for more than 16 hours displayed marked differences in task performance and mood (Cao et al., 2008). Another study demonstrated that medical interns working nights had a significant reduction in visual memory capacity across the night shift (Rollinson et al., 2003).

Performance has been found to also be affected by recent shift history with workers that have worked before 0600 or after 2200 on the previous day showing significantly poorer cognitive performance (Ansiau, Wild, Nniezborala, Rouch, & Marquié, 2008). In the same line, shift length has also been positively associated with the risk of dozing off, increasing for each working hour in the early morning and during the night (McGuffog et al., 2004; Sallinen et al., 2003). Competing research, however, also supports the hypothesis that shifts up to 12 hours do not necessarily lead to a deterioration in performance as long as it is managed properly through the use of flexible working conditions i.e. breaks, and extra recovery days (e.g. Baker & Olson, 1994; Harma et al., 2002; Kallus, Boucsein, & Spanner, 2009).

A large sample study evaluating the long term effects of shiftwork on verbal memory and cognitive performance assessed more than 3200 workers of various occupations. One group of individuals worked shifts and the other had never worked shifts. The cognitive performance of shiftworkers was found to be lower than for workers that had never worked shifts and memory performance tended to decrease with increasing shiftwork. The authors also found that the performance scores increased again after four years or more after participants had ceased to work shifts. The researchers concluded that shiftwork not only leads to short term impacts but also to long term impacts in cognitive functions (Rouch et al., 2005). In effect, there is a large body of research both from the laboratory and the field that supports the effects of circadian disruption on cognitive performance leaving little doubt of the existence of this phenomenon (e.g. Akerstedt, 2007; Folkard, 1996; Kong, 2008; Kuhn, 2001; Van Dongen & Dinges, 2000).

Individual differences have also been found to be of consideration when assessing the impact of shiftwork on performance. One study with nuclear power plant operators found no deterioration of performance during night shifts in experienced operators with the authors believing this was “probably due to lower workload during the night, lack of monotony, and to the processes being relatively inert and forgiving to minor operator errors.” (Gillberg et al., 2003, p.101). These results, which have also been found with surgeons (Duclos et al., 2012) offer some support to the role of experience and the ability to maintain performance levels. Recent research has also started to explore and recognise how individual differences interact with working conditions to affect both performance and well-being. It has been identified that the performance of individuals who have a higher mental involvement and autonomy in their work maintain a fairly static performance through the years whilst the performance of individuals whose work is of a more physical nature show stronger and faster decreases in performance (Costa & Sartori, 2007).

3.6.3.3 Shiftwork and Health

Undoubtedly, the health effects of shiftwork have been the most commonly researched outcomes arising from this type of work arrangements. This research has empirically linked shiftwork to a vast number of diseases, both physical; for example, cardiovascular disease and gastrointestinal disease; and psychological, for example, anxiety and depression (e.g. Geiger-brown, Muntaner, Lipscomb, & Trinkoff, 2004; Harrington, 2001; Knutsson, 2003). This research can be segmented into three separate areas of influence between shiftwork and health. Circadian disruption (e.g. Kuhn, 2001; Smith et al., 2008), disturbed socio-temporal patterns (e.g. Gold et al., 1992; Pisarski et al., 1998), and changes in health behaviours (e.g. Van der Hulst, 2003).

In particular, shiftwork and night work have been linked to cardiovascular disease, where findings, both from single studies and meta-analysis have found that shiftworkers are around 40% more prone to developing cardiovascular disease when compared to day workers (e.g. Boggild & Knutsson, 1999; Anders Knutsson & Boggild, 2000; Van der Hulst, 2003). For gastrointestinal disorders (e.g. indigestion, nausea, heartburn, constipation) shift and night work have been shown to be two to five times more common in shiftworkers than in day workers (e.g. Costa, 1996; Spurgeon, 2003) and there is evidence linking shiftwork with peptic ulcers (Knutsson, 2003). Obesity has also been linked to sleep, and as such, to shiftwork. However well documented this phenomenon is, it is also one that is poorly understood mainly due to its complexity. Food as a regulator and synchroniser of the circadian clock has been advanced as a possible explanation with the intake of food during the night and the following gastric secretions opposing the intrinsic circadian rhythm of enzymatic activity which in turn is regulated by the light/dark cycle (Culpepper et al., 2010). Evidence has also been found with regards to reproductive dysfunction. This is seen mainly in women and is thought might be due to the disruption of the menstrual cycle and from increased stress (e.g. Harrington, 2001; Knutsson, 2003; Spurgeon, 2003). Remarkably, shiftwork has even been associated with an increased risk of contracting certain forms of cancer. Once more, this seems to be more common in women who are exposed to rotating shifts which include night work (e.g. Schernhammer et al., 2001; Wise, 2009). An expert working group at the World Health Organization's International Agency for Research on Cancer has recently concluded that shiftwork that involves circadian disruption is probably carcinogenic to humans (Straif et al., 2007).

Psychological illnesses associated with shiftwork, although less researched than physical complaints, are gathering more research interest and are establishing links between shiftwork, night work, and extended hours work with specific health complaints (e.g. Geiger-brown, Muntaner, Lipscomb, & Trinkoff, 2004; Harrington, 2001; Knutsson, 2003). For example, in a study with 473 nurses it was found that working long shifts was associated with depression, psychosomatic complains, and higher levels of anxiety. Similar findings were mentioned in a general review conducted into the effects of shiftwork and extended working hours (Harrington, 2001). In effect, mental health issues are now recognised as a major cause of sickness absence and work disability (De Raeve, Kant, Jansen, Vasse, & Van den Brandt, 2009), and other research has identified shiftwork as a cause of decreasing general psychological and physical health and well-being of workers (Barnes-farrell et al., 2008). Health outcomes of shiftwork can take many years to manifest themselves, especially for those that work shifts continually for many years. It is theorised that this is the case, due in part, to different levels of adaptation and tolerance to shiftwork (Costa, 1996). However, recent research indicates that it is the severity, rather than the number of health complaints that changes with increasing shiftwork exposure (Barnes-farrell et al., 2008). Finally, unhealthy behaviours, such as smoking, alcohol consumption, poorer diet, and being physically less active, have also been associated with shiftwork (e.g. Nabe-Nielson, Quist, Garde, & Aust, 2011; Van Amelsvoort, Jansen, & Kant, 2006). In effect, the consensus in the research community is that shiftwork is generally a deteriorating factor for workers' health and well-being.

The effects of shift on health are varied and are of the physical, psychological, and psychosomatic nature. Moreover, there are at least two identified mechanisms or pathways that lead to these outcomes. One is of a biological nature which is affected through circadian disruption. The other is of a socio-temporal nature where shiftwork affects health through the desynchronisation with the diurnal orientation of social and family life. Both these mechanisms are also present in on-call work and, as such, it is safe to expect similar unhealthy outcomes to be associated with on-call work.

3.6.3.4 Shiftwork and Well-being

As mentioned before, it is accepted that the negative outcomes of shiftwork occur mainly due to altered sleep-wake cycles, circadian rhythm disruption, and the diurnal orientation of social life (Costa, 2003). The diurnal orientation of social life means that shiftworkers will frequently be out of synchronisation with their friends and family members, affecting not only the well-being of the worker but also of his family members. Moreover, as shiftwork is rarely confined to week days, this effect is further exacerbated as time with children, holidays and social activities are further sacrificed (Williams, 2008). Family routines can be severely disrupted with meal times being changed, children being required to keep quiet and household chores being re-arranged. Some researchers have suggested that due to this desynchrony working shifts may lead to the erosion of social support and to social isolation (Haines III et al., 2008).

It is not surprising, therefore, that research has found that shiftwork schedules have a negative impact on relationship stability, especially for couples with children, or that shiftworkers have an increased risk of divorce and children with anxiety and behavioural problems (e.g. Bianchi, 2011; Presser, 2000). A study conducted with 132 couples found that working shifts was a cause of relationship conflict and depression and that working fixed nights was associated with a six times higher likelihood of divorce for men who had been married for less than five years. For women, the numbers were similar with women married for more than five years and with at least one child being three times more likely to get a divorce (Perry-Jenkins, Goldberg, Pirce, & Sayer, 2007). As a result, it can be said that shiftwork is a potential source of work-life conflict through time and strain based conflicts (Haines III et al., 2008).

Research has also gathered evidence suggesting 12 hour shifts have a greater impact on social and family life than 8 hour shifts. It has been advanced that this is most likely due to the greater amount of time required to recover from longer shifts (Kundi et al., 1995; Loudoun, 2008). Several health complaints such as stress, distress, anxiety, tension, hypertension, an assortment of physical symptoms, emotional exhaustion and burnout have also been found to be some of the health consequences related to the work-family conflict (e.g. Grandey & Cropanzano, 1999; Haines III et al., 2008; Matthews, Priore, Acitelli, & Barnes-farrell, 2006). Hence, it can be said that the work-family conflict literature clearly establishes an association between work demands and workers' well-being (Haines III et al., 2008). What is more, research has indicated that women experience higher work-family conflict than men and that they show lower efficacy in managing these conflicts (Cinamon, 2006; Haines III et al., 2008). Similarly to shiftwork, on-call work leads to altered sleep-wake cycles, circadian rhythm disruption, and is opposite to the diurnal orientation of social life. It can, therefore be expected that on-call will also be a cause of disturbance to the work-life balance of on-call workers with family relationships being affected.

3.6.3.5 Shiftwork summary

This section discussed the general consequences associated with shiftwork, the main intrinsic factors of shiftwork that led to these outcomes, and how these factors are theoretically related to on-call work. It is generally accepted that working shifts leads to circadian disruption, has a negative impact on sleep, and negatively affects the family and social life of workers. Not only this, the extent of these disturbances is moderated by both the features of the shift system itself and by individual and situational differences like age, gender, domestic circumstances, and circadian typology, to name a few. Furthermore, the effects of shiftwork are felt both on physical (e.g. gastrointestinal issues, cardiovascular disease) and psychological health (e.g. anxiety, depression). Performance is another factor which is impacted by shiftwork with the cognitive ability to conduct one's job efficiently and safely being affected (Tucker & Knowles, 2008).

The reception of callouts, when working on-call, are likely to have a direct impact on workers' recovery period mainly through the disruption of sleep. The very character of on-call work means that one might be called back into work at any point between the end of one shift and the beginning of the next. Moreover, this disruption leads to exacerbated circadian disruption and has a clear impact on the social and family lives of workers. It is, as such, not only plausible but very probable that all the effects discussed here in relation to shiftwork are also present in on-call work although specific on-call work factors could moderate this relationship (e.g. number and timing of callouts). For example, it can be expected that on-call work where workers are never or almost never called-out would have a very different impact on circadian disruption, on sleep, and on the social and family lives of workers when compared to workers that receive a high number of callouts.

Circadian rhythms research has shown that diminished ability and increased sleepiness occurs in the early morning hours (between 0200 and 0500). Not surprisingly it has also been shown that these are the times when performance is at its lowest, and sleepiness and the risk of accidents are at their highest (e.g. McGuffog, Turner, & Stone, 2004; Spencer et al., 2006). On-call work, as a type of work that takes place during the night, is subject to these risks.

The relationship between shiftwork, stress, and fatigue can also be expected to exist in on-call work. As a source of stress on-call work can lead to reduced sleep quality and an increase in fatigue that will then lead to increased stress thus completing the cyclical relationship between stress, sleep, and fatigue. With regards to health, similarly to shiftwork, it can be expected that on-call workers will be more prone to suffer from both physical (e.g. cardiovascular issues) and psychological conditions (e.g. anxiety) and demonstrate more unhealthy behaviours, such as smoking, alcohol consumption, poorer diet, and being physically less active (e.g. Nabe-Nielson, Quist, Garde, & Aust, 2011; Van Amelsvoort, Jansen, & Kant, 2006).

3.7 Discussion and Framework

On-call work is fast becoming the most common system of work in the 21st century as a cheap alternative to other types of work. However, both industry and research literature have yet to thoroughly investigate the outcomes of on-call work. The amount of research conducted into the on-call scheduling system of work is in effect very limited. Nonetheless, it has identified a number of issues associated with this type of work. *Proximal* on-call work has, however, received a great deal more attention than the more common, *distal* on-call work. With the distinction between *proximal* and *distal* on-call work in mind there remain still a number of associations that have been found between on-call work and sleep, cognitive performance, and well-being indicators, such as mood, stress, and mental health.

The available research has identified an impact on sleep quantity (Van Gelder &

Kao, 2006) due to higher levels of anxiety about being awoken up by an alarm, or a callout (Torsvall & Akerstedt, 1988). On-call work was also found to have a deleterious effect on cognitive performance and mood (Wesnes et al., 1997), and on well-being (Eurofound, 2012; Heponiemi et al., 2008; Imbernon et al., 1993). Health related impacts have also been identified by other research, namely, on stress, sleep, mental health, and personal safety (Nicol & Botterill, 2004). Moreover, related research into the impacts of sleep disruption and sleep inertia have identified that sleep disruption affects performance (Bonnet, 1985) and well-being (Goyal et al., 2009). The greatest impacts being seen when sleep disruption occurs at a sleep fragmentation rate of around 20 minutes and when disruption occurs in the deeper stages of sleep (Bonnet & Arand, 2003; Tassi & Muzet, 2000). What is more, this research has also identified sleep disruption as a leading cause of fatigue, a result that has been agreed by a large group of international scientists (Åkerstedt, 2000).

To complement the knowledge derived from on-call literature it was decided to explore literature from other working systems with similarities to the on-call scheduling system of work, namely, shiftwork. Although inherently different from on-call work, as shiftwork is not characterised by the uncertainty of when work will occur, it is similar to on-call in the sense that it too causes circadian disruption and can lead to extended working hours. In addition, shiftwork has received a large amount of attention in research over the past several decades. In effect, shiftwork has been shown to be associated with a large number of negative outcomes including fatigue (e.g. Ahsberg, Kecklund, Akerstedt, & Gamberale, 2000; Akerstedt & Wright, 2009; Baulk et al., 2007), stress (e.g. Costa, 2003; Milia, Bohle, Loudoun, & Pisarski, 2008; Sutherland & Cooper, 1996), performance (e.g. Della Rocco, Comperatore, Caldwell, & Cruz, 2000; Rollinson et al., 2003; Signal, 2002), well-being (e.g. Culpepper, Schwartz, & Thorpy, 2010; Jansen, van Amelsvoort, Kristensen, van den Brandt, & Kant, 2003; Tucker & Knowles, 2008), and health (e.g. Eriksen & Kecklund, 2007; Gold et al., 1992; Knutsson, 2003). Not only this but, contrary to what is verified with on-call work, shiftwork literature has also identified some of the specific features of shifts that lead to these outcomes. For example, eight hour shifts versus 12 hour or longer shifts, time of day, time on task, and others. On-call research, on the other hand, has so far provided no such details making our level of knowledge tremendously limited and preventing the creation of practical management strategies and guidelines.

Management strategies and guidelines, similarly to those identified for shiftwork (e.g. Knauth & Hornberger, 2003; Spencer et al., 2006) would provide practical ways of better managing the impacts of on-call work of which fatigue, similarly to shiftwork, is one of the most problematic effects of working hours system when not managed properly. Fatigue, as one of the most prevalent and insidious outcomes of shiftwork and, in effect of most working hours systems, is also an outcome of other working hours systems. It is therefore expected that fatigue will also be a consequence of the impact on-call work has on sleep, by extending wakefulness, and by requiring workers to conduct work in the night and in the early morning (e.g. Imbernon et al., 1993; Van Gelder & Kao, 2006). Not only this, fatigue has also been shown to be associated with physiological and cognitive impairments, mood degradation, higher levels of stress (e.g. Dinges et al., 1997; Philip et al., 2005), and to have a negative impact on the social and personal life of workers (e.g. Friesen et al., 2008; Ku & Smith, 2010). In addition, work related fatigue is for the most part felt even and possibly more intensely after the working day has ended (De Croon, Sluiter, & Fringsdresen, 2003), a situation that becomes more problematic if the recovery time between two periods of work is insufficient (Ǻkerstedt et al., 2000). In this instance on-call work has the potential to exacerbate the impact and the build-up of fatigue by impeding recovery both through the reduction of quality of sleep due to stress and through sleep fragmentation due to sleep disruption by callouts.

As discussed previously, one of the main objectives of this thesis is the development of an on-call work specific framework where the factors at play are represented. Through this review of the available on-call related literature and other related literature (i.e. sleep disruption and shiftwork), and through the knowledge collected in the rail industry discussed in the previous chapter, an initial framework was developed. Due to the limited research conducted regarding the on-call scheduling system of work, the relationships demonstrated in the framework represent majorly theorised relationships between the different factors identified. This framework, shown in Figure 3.1, will, however, be iterated and updated through this thesis as results from each study conducted for this thesis are integrated into the framework.

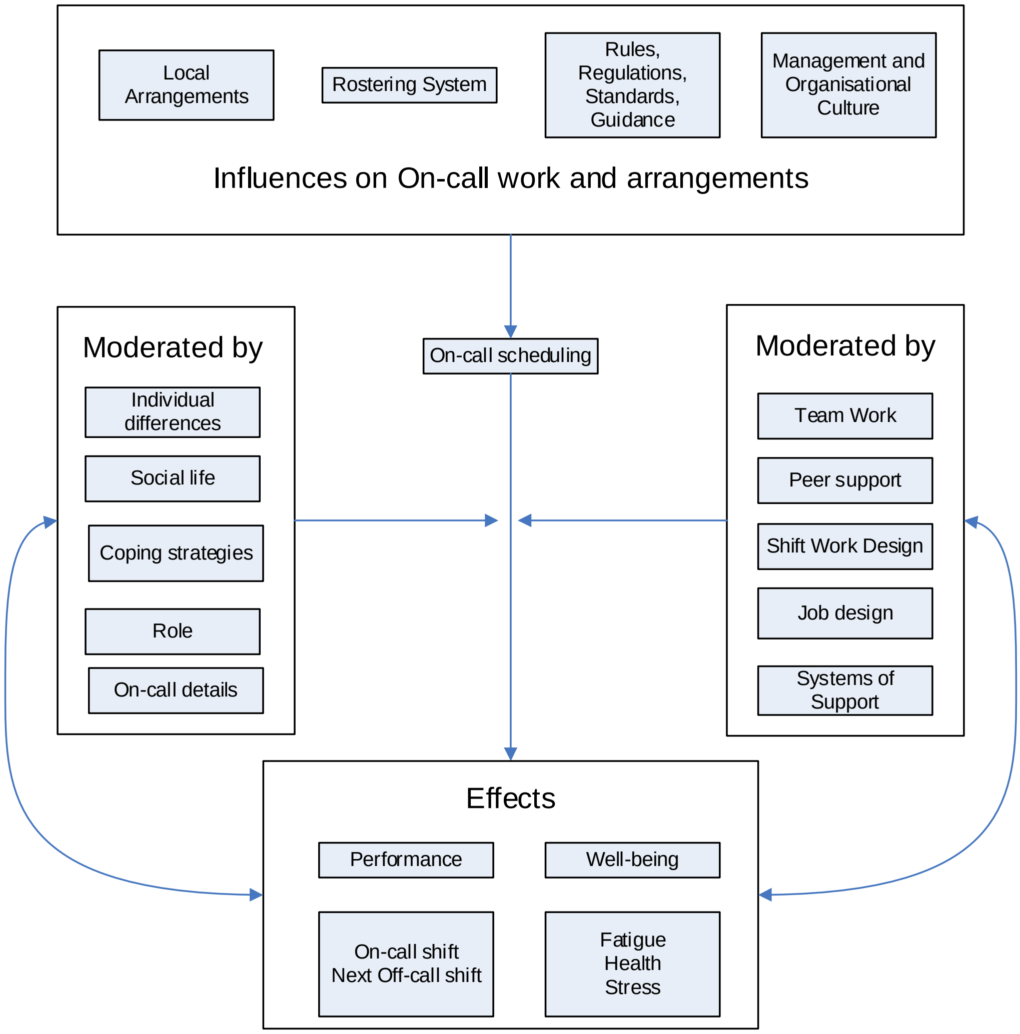


Figure 3.1 - On-call related factors initial framework

The factors in the framework were grouped into the larger categories that reflect the main inputs and outputs of the framework. These are

- Influences,
- Moderators,
- and Effects.

Influences are presented as being different from moderators from a pragmatic perspective. Influences are the inherent characteristics of an organisation (NR in the case of this thesis) which undoubtedly shape the working environment (e.g. rules and regulations) whilst moderators are related directly to the working hours system itself (e.g. on-call details) or the individuals themselves (e.g. social live).

The category of *influences on on-call work and arrangements* reflects the organisation constraints of scheduling and managing working hours schedules.

Shiftwork research has shown that the organisation of rosters is one of the determining factors in the occurrence of the negative outcomes associated with shiftwork (e.g. Bendak, 2003; McGuffog, Turner, & Stone, 2004; Sallinen et al., 2004). Local arrangements, which in the rail industry reflect legacy work arrangements, shape the way on-call scheduling is organised and, as such, also play an important role in the arrangement of on-call work. Although the railways have specific arrangements it can be expected that other industries will have similar issues that will, to a degree, limit the arrangements of work. The same can be said with regards to rules and regulations. Although on-call work seems to exist in a regulation void it does not mean that no influences are present. Quite the contrary, the void left by regulations is filled by other concerns (e.g. financial ones). The final factor of this category; culture, is, in all industries, the one that shapes the objectives and values of the company. In the rail industry it can be said that the prevailing culture is that of the *extra mile* where workers that go beyond their duties are rewarded. This, undoubtedly, plays a role in the organisation of on-call work.

The moderator factors presented in the framework reflect the factors that can be expected to moderate the relationship between on-call work and the effects identified. Individual differences account for a large variation in the ability to deal with shiftwork (e.g. Costa & Di Milia, 2008; Mikko Harma, 1996; Pires et al., 2009). It can be expected that a similar effect exists with regards to on-call work. Likewise, social and family support, as seen with shiftwork, can also be expected to play a role in the ability of on-call workers to cope with this type of work (e.g. Giovanni Costa, 2003; Haines III et al., 2008; Williams, 2008). This is a factor that can also be present in the *effects* category relating to the workers' well-being. More than this, it can be expected that team work, peer support, and coping strategies will all be present as moderators of on-call work and will reduce the negative impacts of on-call work. Similarly to shiftworkers, we would expect that peer support, through the swapping of shifts, would be present in on-call work. Shiftworkers make use of such swaps to help organise and manage non-work related events (e.g. Kallus et al., 2009; Knauth & Hornberger, 2003; McGuffog et al., 2004). A large number of organisational factors have also been found to moderate the relationships between shiftwork and its negative outcomes. Shift design is one of the factors that can play a very large effect on on-call work. At Network Rail, and we can assume this to be at least a possibility in other industries, on-call work is arranged together with shiftwork, with staff working shifts and then covering on-call work when not working their shift. The interaction between the two systems and the different arrangements of both will, undoubtedly, lead to lesser or stronger effects and must, therefore, be considered when designing on-call schedules. Moreover, both on-call literature and sleep disruption literature indicate that call-out factors, such as timing and duration of calls will lead to outcomes of different magnitudes (e.g. Bonnet & Arand, 2003; Imbernon et al., 1993; Martin et al., 1996; Stepanski et al., 1984).

Job design and the role taken by on-call workers can also be expected to lead to different effects, such as, what is required of the worker when receiving a call (e.g. make a safety critical decision, fix a piece of infrastructure). It can be expected that different tasks will be affected differently. Sleep inertia here will be one of the key factors to consider with regards to the ability of a worker to perform his or her duties safely and effectively (e.g. Hofer-Tinguely et al., 2005; Jewett et al., 1999; Wertz, Ronda, Czeisler, Wright, & Owens, 2006). Finally, the number of systems in place for the on-call workers to request support, either to gain advice on the problem facing them or to be replaced if feeling tired and unable to perform duties, can also be expected to moderate the effects of on-call work.

Well-being indicators such as fatigue, stress and health indicators together with performance indicators can also be expected to be affected by on-call work. Not only this, sleep disruption and sleep inertia research also indicate that it is to be expected that performance will be deteriorated for the period of work following a callout. Moreover, it is known that fatigue has broader reaching implications for the social and personal life of workers and due to the impact work and shift design have on it, it also poses problems for the design of work schedules (e.g. Bianchi, 2011; Presser, 2000). Chronic health effects as an outcome of shiftwork have been shown to take years to develop (e.g. Nabe-Nielson, Quist, Garde, & Aust, 2011; Van Amelsvoort, Jansen, & Kant, 2006). The limited time span of this research does not allow for a valid assessment of health effects to be conducted. Moreover, health consequences of on-call work were not within the defined scope for this thesis by Network Rail, the sponsor of this research. For these reasons health consequences of on-call work were not assessed. On the other hand, in the industrial world performance and fatigue are two of clear areas of interest since impacts on these can occur in a short amount of time and can lead to catastrophic incidents.

In sum, on-call work research has, to date, been limited and not much is known about on-call scheduling related factors (Nicol & Botterill, 2004). Factors like sleep indicators and anxiety have been shown to be present in on-call work and to have a deleterious effect on cognitive performance, mood, and on the well-being of on-call workers (e.g. Cooper et al., 1989; Imbernon et al., 1993; Pilcher & Coplens, 2000). Nonetheless there are still many questions regarding not only further impacts of on-call work but the mechanisms in which these impacts occur. Namely regarding:

- The relationship between on-call work and other working hours scheduling systems, and the outcomes of this relationship,
- The level of impact of on-call work on fatigue, stress, performance, and well-being,
- The specific on-call associated factors (e.g. time of callout, number of callouts) that influence key factors, such as sleep quality and quantity, which are associated with performance, fatigue and well-being,
- The specific on-call related factors (e.g. number of on-call shifts, arrangement of these shifts) that influence the outcomes of on-call work on fatigue, stress, performance, and well-being.

This thesis focuses on exploring and assessing some of these questions. Specifically, the research questions for this thesis are:

- What are the on-call arrangements and management procedures at Network Rail?

On-call work research is plagued by a lack of descriptive data (Nicol & Botterill, 2004). On-call arrangements at Network Rail may be Network Rail specific, rail specific, or GB specific. For comparisons to be drawn with other industries and literature the specific on-call arrangements at Network Rail must be detailed.

- How do on-call workers feel about arrangements and management procedures?

To date little is known regarding the impact of on-call work on on-call workers' fatigue, stress, performance, and well-being (e.g. Cooper et al., 1989; Imbernon et al., 1993; Pilcher & Coplens, 2000). From what is known it is clear that on-call arrangements are a factor to consider and, their impacts must, therefore, be documented.

- What are the main impacts of on-call work?
- How do workers deal with these impacts?

It can be expected that on-call work will affect on-call workers' fatigue, stress, performance, and well-being levels (e.g. Rout et al., 1996; Torsvall & Akerstedt, 1988). There may, nonetheless, be other impact factors that the literature has yet to identify. It is important that this thesis explores these possibilities and the coping strategies used by workers as these can point the way to better management procedures.

- What are the on-call specific characteristics that lead to consequences and how do these factors interact?

There are a number of on-call associated factors (e.g. time of callout, number of callouts) that are expected to influence key factors such as sleep quality and quantity, which are associated with performance, fatigue and well-being (e.g. Friesen et al., 2008; Gillberg et al., 2003; Van Dongen, Maislin, et al., 2003; Williamson et al., 1996). The idiosyncrasies of these relationships will provide the information needed to comprehend and manage on-call work.

- How can the negative impacts of the most damaging factors be reduced in industry?

One of the expected outcomes of this thesis is the production of management guidelines for on-call work. These guidelines must, necessarily, include monitoring recommendations as it is expected that the impacts of on-call work are directly related to factors such as the number and timing of callouts.

Based on the available information both regarding on-call work and other working hours scheduling systems such as shiftwork, it is can be expected that:

- Shiftwork arrangements will have an impact on on-call working hours and arrangements,

This is due to on-call work at Network Rail (and potentially within other industries) not being worked in isolation but together with shiftwork.

- On-call rosters are the most common way to organise on-call work,
- The faster the on-call roster rotation the lower the well-being,

It can be expected that a fast rotation of on-call duties (e.g. 1 week in 2 weeks) is more damaging to well-being than a slower rotation (e.g. 1 week in 6 weeks) as it limits the amount of time for recovery. Periods of uninterrupted, continuous sleep have been shown to be the only known way to recover from sleep debt (e.g. Belenky et al., 2003; Totterdell et al., 1995).

- Working on-call has a higher impact on well-being than not on-call work,

Available on-call research has identified that on-call work has a clear detrimental effect when compared to non on-call work (e.g. Heponiemi et al., 2008; Imbernon et al., 1993). These findings are supported by shiftwork research where well-being has consistently been found to be reduced when compared to non shiftworkers (e.g. Grandey & Cropanzano, 1999; Haines III et al., 2008; Matthews, Priore, Acitelli, & Barnes-farrell, 2006).

- On-call workers will experience higher levels of anxiety due to being unable to predict when a callout will take place,

This has been identified by at least one on-call study where ship engineers stated felling anxious due to not knowing when alarms would take place (Torsvall & Akerstedt, 1988),

- The relationship between on-call workers' anxiety and fatigue is mediated by sleep quality,

Stress research has identified both a clear relationship between anxiety and decreased sleep quality (e.g. Doi, Minowa, & Tango, 2003; Edéll-Gustafsson, Kritz, & Bogren, 2002), and fatigue (e.g. Ǻkerstedt, 2006b). More than this, increased number of stressful life events has been found to lead to higher levels of fatigue and that this relationship was mediated by low quality of sleep (Thorsteinsson & Brown, 2009).

- Sleep quality will be lower when on-call than when not on-call due to sleep fragmentation,
- Fragmented sleep due to callouts leads to higher sleepiness during the day after the disruption; with sleep stage and the degree of consolidated sleep

being the factors at play,

Sleep disruption causing fragmented sleep has been shown to lead to increased subjective and objective sleepiness (e.g. Bonnet, 1985; Bonnet & Arand, 2003; Stepanski, Lamphere, Badia, Zorick, & Roth, 1984), with the degree to which sleep is consolidated being a key factors in increased sleepiness (Stepanski, 2002, p 275),

- Sleep inertia is a prevalent and relevant factor for on-call work as it will affect the performance in tasks that involve short term memory, reaction times and vigilance of on-call workers upon waking due to a callout,

Sleep inertia research has clearly identified an association with decreased performance in a broad range of tasks, including reaction times, steadiness and coordination, visual perception tasks, memory tasks, logical reasoning tasks, and several cognitive tasks (Tassi & Muzet, 2000),

- Experience moderates the performance of on-call work; with more experienced workers maintaining higher levels of performance,

- Older on-call workers experience a stronger impact of on-call work than younger ones,

Shiftwork research into individual factors has consistently shown that older workers can find it harder to work shifts (e.g. Costa & Di Milia, 2008; Mikko Harma, 1996; Pires et al., 2009), and with some support found for the role of experience in the ability to maintain performance levels (e.g. Duclos et al., 2012),

- Sleep quality and sleep quantity of on-call workers have a similar impact on the build-up of fatigue,

Sleep quality has been identified as being as relevant or even more relevant regarding fatigue than the actual quantity of sleep (e.g. Dinges et al., 1997; Edéll-Gustafsson, 2002; Pilcher, Ginter, & Sadowsky, 1997; Rosekind, Gander, Connell, & Co, 2001),

- The perception of performance deterioration is affected over time with individuals not recognising the impact of sleep loss and sleep fragmentation on their performance,

On-call work has been found to be associated with declining mood and impaired cognitive performance (Saxena & George, 2005; Wesnes et al., 1997). Wakefulness and sleep debt research also show that when exposed to extended wakefulness individuals lose the ability to assess their own performance decrements (Van Dongen, Maislin, et al., 2003),

- On-call work affects the recovery process leading to higher fatigue levels. This is due to the reduction of recovery time and the disruption to circadian rhythms,

Research has identified that recovery from sleep debt can only be achieved through continuous sleep (e.g. Belenky et al., 2003; Totterdell et al., 1995). On-call work due to its nature (the reception of callouts during the night) will affect both continuous sleep, and by requiring workers to be up during the night, will disrupt circadian rhythms,

- On-call workers suffer more from fatigue than non on-call workers and exhibit effects of fatigue (e.g. poorer performance, elevated risk of incidents, elevated risk of driving incidents),

Both sleep disruption and on-call research have shown that fatigue is one of the main outcomes of fragmented sleep with clear performance deficits being identified also (e.g. Bonnet & Arand, 2003; Saxena & George, 2005; Stepanski et al., 1984),

- On-call work has a negative impact on health conditions both physical and psychological through circadian disruption which has been shown to have an effect on health,

Four specific health related areas have been associated with on-call work. Stress, sleep, mental health, and personal safety (Nicol & Botterill, 2004). Also, on-call workers were found to have more depressive symptoms, and higher levels of tension and frustration (Rankin et al., 1987; Rout et al., 1996),

- On-call work causes disturbance to the work-life balance of workers with family relationships being affected,

On-call research has identified that on-call work affects not only the on-call member of staff but also their family, and reduces family time (Imbernon et al., 1993). Shiftwork research supports these findings with studies identifying large impacts on the family life of shiftworkers. For example, a study conducted with 132 couples found that working shifts was a cause of relationship conflict (Perry-Jenkins et al., 2007),

Table 3.1 presents the main research questions for this thesis derived from literature and how each question is related to each of the objectives of this thesis described in section 1.2 Aims and Objectives in Chapter 1.

Table 3.1 - Main research questions from the literature per objective

	Research questions
Objective 1	• What are the on-call arrangements and management procedures at Network Rail? • How do on-call workers feel about arrangements and management procedures?
Objective 2	• What are the main impacts of on-call work? • How do workers deal with these impacts?
Objectives 3 and 4	• What are the on-call factors that lead to consequences and how do they interact? • What are the callout related factors that lead to unwanted consequences of on-call work?
Objective 5	• How can the negative impact of the most damaging factors be reduced in Industry?

3.8 Chapter Conclusion

Expanding on the on-call regulation in GB and in Europe and on the arrangements in place in the rail industry to manage on-call work discussed in the previous chapter, in this chapter the available on-call literature was also explored. Due to the limited amount of on-call specific literature, shiftwork, as a much more researched scheduling system of work, was also analysed and similarities were drawn with the on-call scheduling system. The main effects of this type of work, and fatigue, as one of the main negative outcomes, were also explored in greater detail where the causes and effects were assessed. In addition, sleep disruption and sleep inertia research were also discussed as these provide an invaluable insight into one of the inherent characteristics of on-call work. Receiving calls at all hours of the day and night will undoubtedly lead to sleep fragmentation and to the effects this has on performance and fatigue, both through sleep inertia and by impeding sleep and, as such, preventing recovery from fatigue. The chapter concluded with the presentation of an on-call specific framework where factors identified in literature and theorised based both on non on-call literature, shiftwork literature, and the knowledge acquired and discussed in the previous chapter are represented.

Chapter 4 – Research approach and methods

4.1 Chapter summary

This chapter describes and summarises the research methods used in this thesis to explore the idiosyncrasies of the *distal* on-call system work. As described in the previous chapter, on-call available research suffers from many limitations. One of the most relevant is the lack of descriptive data regarding the different on-call arrangements in literature. An incremental approach was therefore adopted for this thesis, where each research method was chosen based on the findings of the previous method. This was necessary both due to the lack of existing on-call research and due to the lack of descriptive data. In the same way, this chapter is also arranged in an incremental format as it reflects how each method influenced the choice of the next. The choice of methods for each research study are presented in detailed and discussed and the chapter concludes by connecting each method with the main objectives of this thesis exposed in Chapter 1.

4.2 Background

Chapter 2 explored the on-call work management arrangements and regulation in place in GB railways and in Europe. This review identified a lack of on-call regulations. Notwithstanding, this has not prevented companies from utilising on-call work without the aid of research based guidelines or policies. Chapter 3 then explored the available on-call literature which was also found to be limited. Due to this, related literature was also explored with sleep disruption and sleep inertia research also being discussed as these provide an invaluable insight into one of the inherent characteristics of on-call work. Receiving calls at all hours of the day and night will undoubtedly lead to sleep fragmentation and to the effects this has on performance and fatigue, both through sleep inertia and by impeding sleep and, as such, preventing recovery from fatigue. Shiftwork literature, as a much more researched scheduling system of work, was also analysed and similarities were drawn with the on-call scheduling system. The main effects of this type of work, and fatigue, as one of the main negative outcomes of working hours systems were also explored in greater detail. From the available regulation and literature data, both regarding on-call work and non on-call work, an initial on-call related factors framework was created. The chapter concluded by identifying the main research questions regarding the impacts of on-call work and the mechanisms in which these impacts occur and which this thesis aims to answer. These are:

- What are the on-call arrangements and management procedures at Network Rail?
- How do on-call workers feel about arrangements and management procedures?
- What are the main impacts of on-call work?
- How do workers experience and deal with these impacts?
- What is the relationship between callouts and the perceived consequences of on-call work?
- What is the relationship between on-call work arrangements and management procedures?
- What are the on-call specific characteristics that lead to consequences?
- How do these factors interact and what are the consequences?
- How can on-call work be monitored?
- What are the most damaging factors associated with on-call and how can they be modified to reduce negative consequences?

4.3 Methodological challenges

The study of on-call work, much the same as most other topics of research, presents some challenges. In this section these challenges will be described and discussed and a review of the methods used to analyse this type of working hours scheduling are presented. Further methods used to investigate other working hours systems, namely shiftwork, are also discussed to provide a wider understanding of the potentially available methods to investigate on-call work.

4.3.1 On-call methods

The inherent unpredictability of on-call work makes it challenging to observe and assess. On-call work can be expected to present a high variation of events where it is possible that on-call staff do not receive any callouts for the duration of their on-call shift. Another difficulty is the inability to observe on-call workers directly. When assessing *proximal* on-call workers such difficulties are reduced and can even be eliminated. *Distal* on-call workers on the other hand are usually away from work when they are called in to work. This prevents direct data collection and other methods must be used; relying either on the recollection of the on-call event, or requiring the on-call worker to be trusted to note down the details of the callout when it occurs. A further challenge in the investigation of on-call work is its interaction with shiftwork. All other working hours systems usually occur by themselves. On-call work on the other hand seems to be combined with shiftwork where on-call workers only work on-call during the periods between shifts. The influence of different shifts must be expected to cause different impacts on on-call shifts.

On-call (both *proximal* and *distal*) research work to date has been investigated using a number of different methods. There has been at least one study that used semi-structured interviews (Rout, 1996), while the large majority (at least eight) have used postal questionnaire surveys (e.g.Cooper, Rout, & Faragher, 1989; Sutherland & Cooper, 1996). At least two have used activity logs (Imbernon et al., 1993; Pilcher & Coplens, 2000), one has used electroencephalogram and electrocardiogram recordings (Torsvall & Akerstedt, 1988), and one has used actigraphs (Van Gelder & Kao, 2006). Also, as discussed in Chapter 2, in the initial stages of this research, on-call work was also explored through exploratory interviews and semi-structured interviews (audits).

Although these methods are varied, the results yielded a lack of descriptive data and knowledge regarding this system of work. For a system that has received so little research attention the lack of descriptive data into its intricacies represents a grave limitation into the definition and analysis of said system.

4.3.2 Shiftwork methods

A great variety of methods have been used to explore the intricacies of shiftwork. This is both due to the ease of observing shiftwork and the sheer amount of research conducted into this type of working schedule. All the methods used to investigate on-call work have also been used to investigate shiftwork but many others are also used.

Shiftwork researchers have conducted research both in laboratory settings and real world settings. Laboratory setting studies have been used to explore a large number of shift related issues. Contrary to shiftwork where much laboratory based research has been conducted, on-call work research has so far focused on real world situations. However, in the laboratory, sleep disruption research, whilst not on-call research, has offered great insight into some of the processes of on-call.

Outside of the laboratory many other methods have been used with interviews and questionnaires being the most common. Many longitudinal studies have also been used in shiftwork to assess long term impacts of this working hours system (C Ribet & Derriennic, 1999; Rouch et al., 2005; Van Amelsvoort et al., 2006). These studies have assessed both health effects of working shifts for long periods and the propensity to initiate and maintain unhealthy habits like smoking, and also other long term impacts in cognitive ability and the long term effects of circadian disruption. In the quest to understand shiftwork, researchers have also made use of many other less known and utilised methods. For example, a recent study, using chronotype questionnaires, compiled participants' shift history and assessed how individuals of different chronotypes deal with shiftwork. In the same study, researchers also used genetic markers to explore this relationship (Gamble et al., 2011). All these methods can also be used to investigate on-call work and provide a greater insight into this type of working hours scheduling system.

In shiftwork research studies conducted using questionnaires, different formats have been used with many different scales. This section will quickly discuss some of the most common and well documented ones. The Karolinska Sleepiness Scale (KSS) has since its development been one of the most used self-assessment sleepiness/fatigue scales (Akerstedt & Gillberg, 1990). The KSS has been tested against more objective sleepiness measures, namely Electroencephalographic (EEG) and the Accumulated Time with Sleepiness (ATS) with high correlations ($r=0.56$ to $r= 0.65$) being verified (Akerstedt & Gillberg, 1990; Kaida et al., 2006). The KSS is a 9-point scale varying from 1 – "Extremely alert" to 9 – "Extremely sleepy, fighting sleep".

Since its creation, the Standard Shiftwork Index (SSI) has become probably the most frequently used tool to assess the details and impacts of shiftwork (Barton, Spelten, Totterdell, Folkard, & Costa, 1995). The SSI is comprised of six sections and covers a large number of factors. Section one covers biographical information, section two assesses sleep quality and quantity, and fatigue. Section three assesses health and well-being, section four assesses social and domestic factors. Section five assesses the ability to cope with shiftwork and section six assesses circadian typology. The questionnaire is comprised of a number of validated scales such as the General Health Questionnaire (Goldberg, 1972) and the Coping Strategies Inventory (Tobin, Holroyd, & Reynolds, 1984). Since its creation, the SSI has been extensively used by the shiftwork research community and, although incomplete, research has found support for parts of the model underpinning the questionnaire survey (Tucker & Knowles, 2008).

4.4 Overall methodology

As the previous section demonstrated, a large number of methods have been used to investigate shiftwork and, to a lesser degree on-call work, both in and out of the laboratory. The available methods to use in this thesis were, as a result, vast and afforded several possibilities. In this section the methods selected are discussed in light of the available methods and of the information available at the beginning of the research work from the initial work described in Chapter 2.

Given the lack of descriptive data that appears to prevail in on-call work research, an incremental approach was decided upon. It was decided that firstly it would be required to understand the on-call scheduling system before exploring the relationships between the different factors identified and theorised. A large number of interviews were conducted with Network Rail’s members of staff where obtaining this descriptive data was one of the main objectives. This was the first study conducted for this thesis.

It was decided that the second step would be to assess the generality of the findings of Study 1 by conducting in a large scale survey, the content of which would be dictated at least partly by the results of the interviews. This was to be Study 2 of this thesis. Both studies 1 and 2 required participants to recollect feelings and details regarding on-call work. To overcome this limitation it was decided that Study 3 would collect real time data to allow both for the comparison of factors between a week on-call and a week off-call, and to assess the direct impact of specific callout events (Bolger, Davis, & Rafaeli, 2003; Lida, Shrout, Laurenceau, & Bolger, 2012; Stone & Shiffman, 2002). To do this, volunteers were asked to keep an activity log of their callouts and the impact felt by each callout. A visual representation of a research framework demonstrating how earlier methods supported later ones is presented in Figure 4.1.

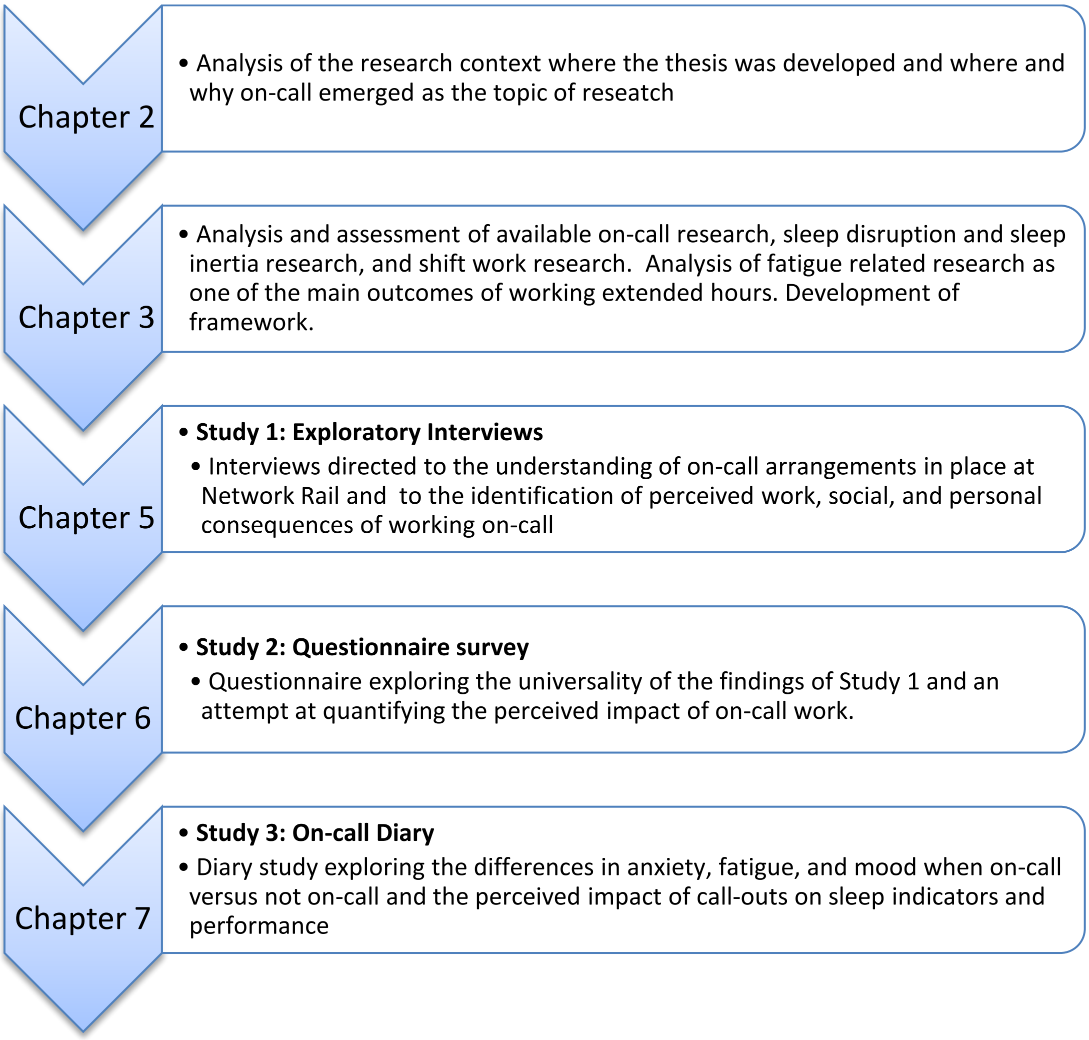


Figure 4.1- Research contextual framework

A description of each method and the reasons for its choice are presented in the subsequent sections of this chapter and the application of the method is discussed in the relevant study chapter.

Ethical approval for all three studies was sought from the Faculty of Engineering Ethics Committee of the University of Nottingham. Approval was awarded with no changes required as it was shown that the studies met all ethical guidelines. These guidelines were developed in accordance with British Psychological Society ethical guidance (BPS, 2009). Participants were briefed on what was expected of them if they decided to take part in the study. They were informed that participation in the study was voluntary and that they were able to withdraw their participation at any time, even retrospectively and details of whom to contact should they wish to withdraw. They were informed that all data collected would be treated securely and in the strictest confidence and that all data would be made anonymous and compiled to a database prior to treatment and usage in any reports.

4.5 Study 1: Semi-structured interviews

The preliminary work conducted at Network Rail previously to the definition of on-call work as the topic of this research, and discussed in Chapter 2, together with limitations identified in the literature, discussed in Chapter 3, shaped the direction and objectives of this thesis. Study 1 aimed initially to address mainly the first two objectives of this thesis:

1. Identify and describe the on-call arrangements and management practices in place at Network Rail,
2. Describe the perceived work, social, and personal consequences of working on-call on workers.

At the beginning of the research the author knew little about the on-call scheduling system of work and little information was available both in the literature and in the rail industry. Descriptive data was, therefore, required to allow the understanding of this system of work scheduling. It was necessary to identify how on-call work is planned and managed, how it interacts with the other systems of work in place in the company, i.e. office hours, shiftwork, and 24/7 coverage. Secondly, it is one of the objectives of this thesis to explore the outcomes or consequences on-call work produces on workers and their families. To gather this data it was decided that Study 1, through a semi-structured approach, would explore the emergence of these, and other factors.

Furthermore, it was expected that the data collected would provide valuable knowledge to also pursue objectives four, five and six:

4. Develop an on-call specific framework where factors that are of importance are represented and so are the relationships between them,
5. Develop a set of research based guidelines on how to better manage the risks associated with on-call work,
6. Develop and test a data collection method to implement at Network Rail to collect on-call data.

4.5.1 Data capture

Interview data can be collected and analysed through a number of qualitative methods (and some quantitative ones also). The objectives the data analysis aims to achieve and the way the data is collected influence directly the choice of method used to analyse interview data (Robson, 2002). It was decided that a grounded theory oriented approach to data collection would be the more suited approach to fulfil the objectives of these interviews as it effectively allows the discovery of concepts and hypotheses from the field (Strauss & Corbin, 1998).

A semi-structured interview was compiled based on the amount of knowledge the researcher possessed at the time regarding the on-call system of work acquired through other pieces of work discussed in Chapter 2. The questions were then assessed by two Ergonomics Researchers from the University of Nottingham before a final script was compiled. The first part of the interview script was compiled to explore the arrangements of on-call work and the details of how on-call events are managed. The second part was designed to address the impacts felt and coping strategies used to deal with on-call work by interviewees. In accordance with the principles of grounded theory the questions were constructed based on the principle of immersion of the researcher in the context being studied (Hayes, 2000). The interview script together with the focus area of each topic is shown in Table 4.1.

Table 4.1 - Semi-structured interview script

Number	Questions and probes
1	Can you tell me about how the on-call system works for you? • How many times on-call / intensity of work / hours of sleep? How many days a week? How it is scheduled? • How long is your commute?
2	Why do you need to work on-call hours? • Is it mandatory or can you chose not to do it? • Why would you choose not to do it?
3	What are the most common reasons for you to be called? • Leave the house/telephone consultation? • Are the calls appropriate/justified? Do you need to be involved?
4	Can you give me an example of a typical episode of what happens when you are on-call?
5	How often do you get a call when on-call on average per night? Per week? • Worst case scenario? Best case scenario?
6	What type of actions can you be required to do when on-call? • How do you decide which action is the most appropriate?

	• What criteria do you use to escalate your involvement?
7	How do you feel about on-call work? • What works for you in this system and what doesn't? • What would you change about it?
8	What do you feel your role is when on-call? • What does it mean to you?
9	Do you receive emails/sms/phone calls even when not on-call? • Co-workers asking for advice? / Information on what is happening? /etc. • What motivates you to receive this information/being always contactable?
10	What system of work do you follow when not on call? • Shifts? Rotating shifts? Schedule?
11	How does your life change when you are on-call?
12	What impact does working on-call hours have on your life? • **Well-being –** Family, Social, Health
13	Do you feel on-call work affects your **fatigue** and/or **stress** levels? • How?
14	Do you feel on-call work has an impact on your work?
15	What ways of coping with on-call work do you use? • Can you refuse to work on call? • Do you refuse? Why do you refuse/not refuse? • How do these methods work for you? • How often do you need to use them?
16	Do you use hobbies to cope with on-call work? • What benefits do you get from these?

4.5.2 Data analysis

An inducted thematic analysis approach was the preferred method of analysis. This method was chosen as it allows themes to emerge from the data and not from a coding framework established beforehand (Miles & Huberman, 1994). Furthermore, it was also expected that the problematic nature of on-call work would be focused on a specific number of topics or themes. Although a coding framework was developed earlier, and certain connections were expected, it was decided that due to the lack of knowledge regarding the topic an inductive approach, where themes are allowed to emerge, would yield richer data. This was indeed the case with many themes not initially considered in the framework arising from the data. To assess the existence of variability in the data from either geographic location or due to local arrangements the data collection was conducted in five separate Delivery Units across GB.

All interviews were recorded using a dictaphone and all information was reviewed and analysed by the interviewer periodically. This allowed for an initial coding to take place and for an iterative process of analysis and revision to be used throughout the study. This made it possible to assess the initial interview script and make modifications to the protocol, such as the addition of probes, or the removal of questions. Although the script used was maintained throughout the whole process, significant, unpredicted topics were identified and added to the list of probes. These changes did not significantly change the script but added relevant information to the exploration of the on-call system of work. This approach is consistent with a grounded theory approach as interviews were still oriented by inductive principles and not deductive ones (Hayes, 2000; Miles & Huberman, 1994). Table 4.2 shows a few examples of the themes identified and some of the quotes that led to its identification.

Table 4.2 - Example of themes and quotes from Study 1

Theme	Quotes
Swapping and Covering	"Well we're flexible here, which is good. As long as I give them plenty of notice or they give me plenty of notice, we can swap things around", P7) "So yeah there'll always be changes. Someone might go on a course. Somebody might be ill. Someone might need to take short term leave. Someone might just want to swap because they want to go out. So yeah, it's quite common, they'd be a change every week" (P68)
Family and social life impact	"Obviously it disturbs me but obviously it disturbs family as well" (P64). "The simple answer is yeah, social life is affected", P6).

4.6 Study 2: Survey questionnaire

The interviews conducted in Study 1 identified a large number of factors associated with on-call work. Study 2 aimed to investigate the distribution and generality of these findings. To do so, a questionnaire survey was constructed and an invitation of participation was sent-out across the Infrastructure Maintenance organisation. Both for this study and Study 3 only managerial level members of staff were considered as

Study 1 identified them as being more at risk than frontline staff. The questionnaire was divided into three sections designed to assess different aspects of the on-call system of work. Section one focused on on-call arrangements, section two on the impacts of on-call work versus non on-call work, and section three assessed the overall views of participants regarding on-call work. A fourth section assessed the demographic factors thought to potentially have an influence on on-call work.

The sequencing of questions was carefully planned and the concepts of priming, funnelling and reverse funnelling were carefully used (Hayes, 2000, pp.79). In accordance to these principles the initial questions explore on-call arrangements, then the questions expand (reverse funnelling) to a more general range of questions regarding the impacts of on-call work and overall views. The questions then become more specific again about on-call arrangements (funnelling) and conclude with simple demographics. The same principles were used in each section of the questionnaire, for example in the *About Work* section the first question is specific – "How many hours of sleep do you get on average per 'night'?" and then expand to more general sleep disruption and fatigue related questions. The same can be said about priming where each section begins with a specific question to prime the participant to each sub-theme. For example, the *Overall views* section starts by ascertaining the general degree of satisfaction of the participant and then proceeds to explore the factors that contribute to this satisfaction. The questionnaire can be found in Appendix A - On-call questionnaire survey.

The focus of most on-call questionnaires is on the health impacts of on-call work. Assessing the health impacts of on-call work was not one of the objectives of this work. This, together with the potentially peculiar arrangements of on-call work in the rail industry, led to the decision not to base the questions of the survey on on-call questionnaires from on-call studies identified in the literature (e.g.Cooper, Rout, & Faragher, 1989; Sutherland & Cooper, 1996). Instead the survey was constructed based mainly on the data collected in Study 1 but where possible validated scales and questionnaires were used as reference. The Rail Ergonomics Questionnaire (REQUEST) and the Standard Shiftwork Index (SSI) were the two main sources used. The data and knowledge collected in Study 1 were used across the questionnaire to direct the construction and modifications to every question. All the on-call arrangements and several other questions were created and compiled based on the work conducted in Study 1 and represent the factors indicated as being of relevance in on-call work. REQUEST is a questionnaire developed specifically for GB railways and has been in use since 1998 (Ryan, Wilson, Sharples, Morrisroe, & Clarke, 2009). As a validated tool in the railways it was an invaluable source of guidance for the design and general organisation of the questionnaire. The demographic data was also collected using REQUEST questions and scales.

The SSI was used as the basis on which to construct on-call specific questions by modifying and adapting shiftwork questions to on-call ones. Some questions were easily modified simply by changing *roster or shift* to *on-call*, whilst others were modified further to reflect the idiosyncrasies of on-call work. For example, *working shifts* in question 1.7 of the SSI was modified to *working on-call* (Question 25 in on-call questionnaire) whilst for questions 2.4 to 2.11 of the SSI the response options were also modified to reflect on-call work (Questions 14 to 17 in the on-call questionnaire)[5]. Moreover, through the review process discussed in the next section many of these scales were reduced with only parts of the scales being used in the final version of the questionnaire.

4.6.1 Iteration procedure

The final version of the questionnaire was achieved after several reviews both through ergonomic researchers, ergonomic practitioners, and Network Rail senior management staff. Figure 4.2 shows a visual representation of the construction process. The process was initiated by compiling an initial set of 84 questions based on the findings of Study 1, the SSI, and REQUEST. These were then assessed by three ergonomics researchers from the University of Nottingham including two of the researchers involved in the creation and review of REQUEST. Comments and recommendations covered a wide range of issues from the order and amount of questions, to the wording of the questions and the use of scales. It was recommended that the questionnaire should aim to take no longer than 20 minutes to complete in order to attempt to increase the sample size, a recommendation made both by the researchers and later by a senior manager at Network Rail. It was thought that on-call staff would not be willing to relinquish more time for participation in this study.

In particular, it was recommended that all scales in the questionnaire were modified

[5] For more details on the Standard Shiftwork Index please refer to Barton et al., 1995.

to 5-point scales and that anchors were used instead of a full description for each point of the scales. It was recommended that the number of questions should be reduced and recommendations on how to do so were presented. With regards to the wording of questions, recommendations aimed at making the questions clearer both with regards to the wording and answering format, for example by substituting *superior* for *manager*. It was further recommended that the demographics section should be moved to the end of the survey instead of being presented at the beginning, as it is both in the SSI and REQUEST, as the on-call arrangements questions were already straight forward and could be used to prime on-call work. Table 4.3 presents a summary of the question items, the section of the questionnaire they belong to and their source.

Table 4.3 - Source table

Question	Section	Items	Source
1	On-call arrangements	Time working on-call	Study 1
2		On-call level	
3		On-call frequency	
4		Maximum consecutive on-call days last month	SSI
5		Maximum consecutive on-call days ever	Study 1
6		Has on-call roster?	
7		Advance notice on on-call roster	
8		Average number of calls when on-call	
9		Average percentage of calls after going to sleep	
10		Percentage of calls which disrupt sleep	
11		Worse time to be called?	
12		When is this period?	
13	About work	Sleep scale	SSI
14		Sleep scale	
15		Sleep scale	
16		Sleep scale	
17		Sleep scale	
18		Longest period working on-call without sleep	Study 1

19		Performance scale when attending site	
20		Performance scale when on telephone consultation	
21		Stress	
22		Anxiety	
23	Overall views	Work satisfaction	SSI
24		Free time satisfaction	
25		Partner supportive of on-call work?	
26		Impact of on-call work	
27		Impact of on-call work	Study 1
28		Impact of *normal* work	
29		On-call when on leave	
30		On-call on day off	
31		On-call on day off	
32		On-call on day off or leave	
33		Work swapping	SSI
34		On-call requirement	Study 1
35		On-call requirement	
36		Reasons to work on-call	SSI
37		Willingness to work on-call	
38	Demographics	Age	REQUEST
39		Gender	
40		Time in rail industry	
41		Time in current position	
42		Delivery Unit	
43		Working hours per week	

Based on this analysis and recommendations, version two of the questionnaire was compiled and set up online. It was decided to host the survey on-line as this would allow participants to access it at will and both through their computers and telephones. Eight Human Factors practitioners from the Ergonomics team at Network Rail and two Ergonomics researchers at the University of Nottingham were then asked to pilot the questionnaire and to comment on the design, order of questions, relevance of questions, general questionnaire design, and the time required to complete the survey. A number of typographic and general errors were found and a large number of recommendations were made regarding the content, the layout and the navigation through the website. These comments and ideas were then incorporated into the design where appropriate, and version three of the questionnaire was created.

A further four Human Factors practitioners and a senior Infrastructure Maintenance manager at Network Rail were then asked to conduct a final review and assess the time required to complete version three of the questionnaire. Total completion time ranged from 12 to 18 minutes, which was within the amount of time recommended. No final recommendations were made to version three of the questionnaire and this version became the final version of the questionnaire and roll out to the population was prepared.

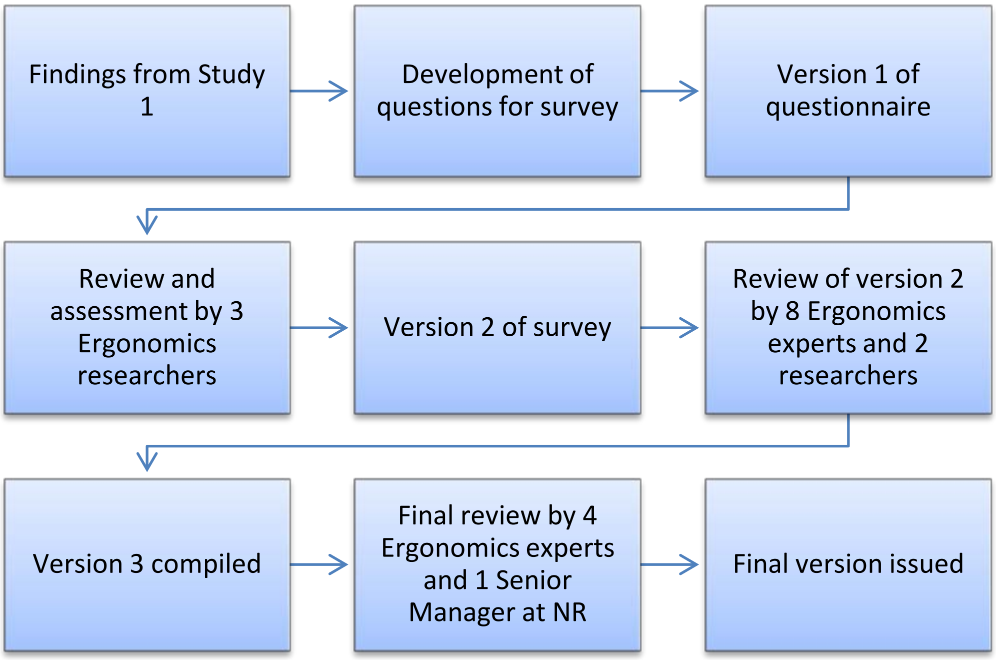


Figure 4.2 - Questionnaire construction process

4.6.2 Implementation and delivery

With the objective of collecting data across the whole company and, as such, across GB, and with the objective of maximising the response rate, a number of steps were taken. The survey was held online in a Network Rail platform – Ergotools – which made it automatically available to all members of staff in the company. It was formatted so that it could be completed both from a computer or a Blackberry telephone as these are widely used by Network Rail managerial staff. Furthermore, invitations were sent out via email to the target population (around 800 members of staff) by a senior Infrastructure Maintenance manager at Network Rail. Providing easy access to the survey and making use of a person of authority are two known ways to elicit higher response rates in questionnaire surveys (Hayes, 2000). The same manager also reviewed the survey invite and his recommendations were incorporated into the invite. A copy of the invitation email is shown in Appendix B - Questionnaire invite.

Data collection started on 12th December 2011 and lasted six weeks. It is common for staff to be on annual leave over the Christmas period so by choosing this date and this length of time for data collection it was expected that the response rate would be increased as more staff would be able to find the time to respond to the questionnaire. Two reminders were also sent out to the whole population (no individual data was collected so a targeted approach was not possible). The first was sent out half way through the data collection period and the second at the end of the fifth week. At the mid-way point more than 300 questionnaires had already been returned and by the end of week five more than 400 had been returned. At the end of the study a total of 479 questionnaires had been returned (around 60% of the estimated population of 800). There is no reason to suppose that this is a biased sample or that these results do not represent the views across the whole population.

4.6.3 Analysis approach

The data collected was analysed through the use of both descriptive and multivariate statistics. The analysis was conducted using version 20 of the Statistical Package for Social Sciences (SPSS). Several multivariate statistical tests and models were used to analyse the data. All rating scales used to collect data were treated as interval. This is common practice with rating scales as they make use of anchors associated with a scale (1 to 5 through the work conducted for this thesis) (Hayes, 2000). On-call and off-call data was compared through the use of T-tests. Multiple correspondence analyses were used to explore the existence of sub-groups in the data. Analysis of Variance (ANOVA) tests and linear regressions were used to explore the differences between the different on-call scenarios and to test a number of hypotheses regarding which factors can be associated with the negative outcomes of working on-call identified. For example, an ANOVA was used to assess the prediction that the longest the period working on-call the lowest the satisfaction, with the amount of time on-call work leaves for the worker's life. The use of these methods and the results of these analyses are presented in detail in Chapter 6.

4.7 Study 3: Diary

Study 1 identified the idiosyncrasies of on-call work through a large number of interviews and the survey questionnaire conducted in Study 2 assessed the generality of these findings for on-call managers. Study 3 was designed to help clarify the particular relationship between being on-call, being called-out and fatigue, anxiety performance, and mood. By collecting data in real time this study aims to eliminate recollection bias (Stone & Shiffman, 2002) and provide a clearer image regarding differences between on-call weeks and not on-call weeks, also allowing the gathering of specific data regarding the number and timing of callouts. Furthermore, this allows further exploration of the relationship between number and timing of callouts and how these have an impact on the ability of workers to perform their duties.

Diary studies, although a very powerful way to collect data by aiming to eliminate recollection bias, also suffer from a number of limitations. One of them being the size of the diary to be kept, where the burden of repeated questions and responses places great demands on the participants (Bolger et al., 2003; Lida et al., 2012). To combat this, researchers are required to design shorter instruments that limit the depth of the investigation. This study was not an exception to this and as a result data collection was limited to a small number of factors.

A large number of factors relevant to on-call work had been identified both in the available and relevant literature and from the findings of studies 1 and 2. Nonetheless, due to the limitation in size required for diary studies, it was decided to limit the data collection to the most relevant factors identified, namely, anxiety, fatigue, stress, mood, sleep indicators, and callout details including performance. Although not being identified as an affected factor when on-call in the questionnaire survey, performance has been shown by research to be affected after sleep disruption probably due to sleep inertia (e.g. Hofer-Tinguely et al., 2005; Miccoli, Versace, Koterle, & Cavallero, 2008), and it was hypothesised that this would be the case when receiving a callout. Participants were asked to provide scores for anxiety, fatigue, and mood, at the start of their on-call shifts. When going to bed they were asked the time they went to bed, and during the night participants were asked to log the time of each callout, the length, if they were asleep, if they were required to leave the house, how able they felt to perform their duties (perceived performance), and the estimated time when they went back to sleep. In the morning after waking up participants were asked once again to provide scores for anxiety, fatigue, and mood, but also a sleep quality score, the time they got up and an estimate of when they fell asleep after going to bed (sleep latency). Here also, to maintain consistency with the previous study it was decided to use the same five point scales used in Study 2.

Diary studies can be divided into two separate types: time-based designs and event-based designs (Bolger et al., 2003). For the current work an event-based approach was adopted where subjective ratings of anxiety, fatigue, mood, and sleep related data were collected at the beginning of the on-call shift / end of the *normal* working hours and when getting in and out of bed in the morning. Callout data was collected upon the event of a callout.

4.7.1 The format of the diary

The literature identifies and discusses two main methods of collecting data in diary studies; pen and paper or through the use of hand held computers (Feldman Barret & Barret, 2001; Shiffman, 2000). Both have their own limitations and both present difficulties. One difficulty that is common to both methods is that training is often required on how to record the data. The burden of recording of data for long periods of time is another. Pen and paper diaries, although simpler and more straight forward to use for most participants, are more vulnerable to forgetfulness and as a result can lead to retrospective errors. It is not uncommon for participants to forget to record their data for a number of reasons; failing to remember the scheduled response times or failing to have the diary at hand are just two. Hand held computer methods go some way to solve these issues by providing time-stamps on the answers and by incorporating alarms to remind the participants to record their data. However, costs, and the high level of training required for some participants are severe limitations of hand held computer diary studies (Bolger et al., 2003).

For this study it was decided to use a new approach that would eliminate the need of training and would ensure that the participants always had their diary at hand, but which also presented its own difficulties – the Blackberry telephone. Blackberry telephones are widespread in Network Rail and are a tool participants are proficient at using. Blackberry telephones (or at least email enabled telephones) are now an indispensable tool in the rail industry and their use is as common as the use of computers. Additionally it is the means by which on-call staff receive their callouts. Based on these considerations it was decided that in order to facilitate the training and increase the response rate in the study by facilitating the recording and maintenance of the data, the Blackberry telephone would be the chosen data collection method. The main problem of choosing this method was the lack of specific software designed to conduct diary based research in Blackberry telephones. To overcome this issue it was initially thought of designing a telephone application that would run a diary protocol. Unfortunately, as these are corporate telephones a large number of restrictions are in place and it was found that overcoming these limitations would not be feasible within the timeframe for this thesis.

As a result the diary protocol was prepared in a Microsoft Excel 2003 spreadsheet as this is both a piece of software available in the telephone and one which the participants are proficient at using. Table 4.4 shows the final version of the table developed.

Table 4.4 - Diary table

At the beginning of on-call shift		
Anxiety	Fatigue	Mood

For each callout record:						
	Time	Ended	Asleep	Out	Ability	BTS
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

In the morning:			
In bed at	Asleep	Got Up at	Sleep quality

Anxiety	Fatigue	Mood

NOTE	1 = Low / Good	5 = High / Bad

When creating the diary sheet one of the objectives was to make it as simple to use as possible. Unfortunately the Blackberry platform does not allow macros to be run and as such the design possibilities were limited. The diary was designed to fit perfectly on the width of the Blackberry's screen so that participants were only required to scroll down to move through the different sections of the diary and not sideways. Figure 4.3 shows the final version of the diary. As described before, the diary protocol went through a number of revisions before the final version used was achieved. The final version of the diary protocol, including the manual, is presented in Appendix B - Questionnaire invite.

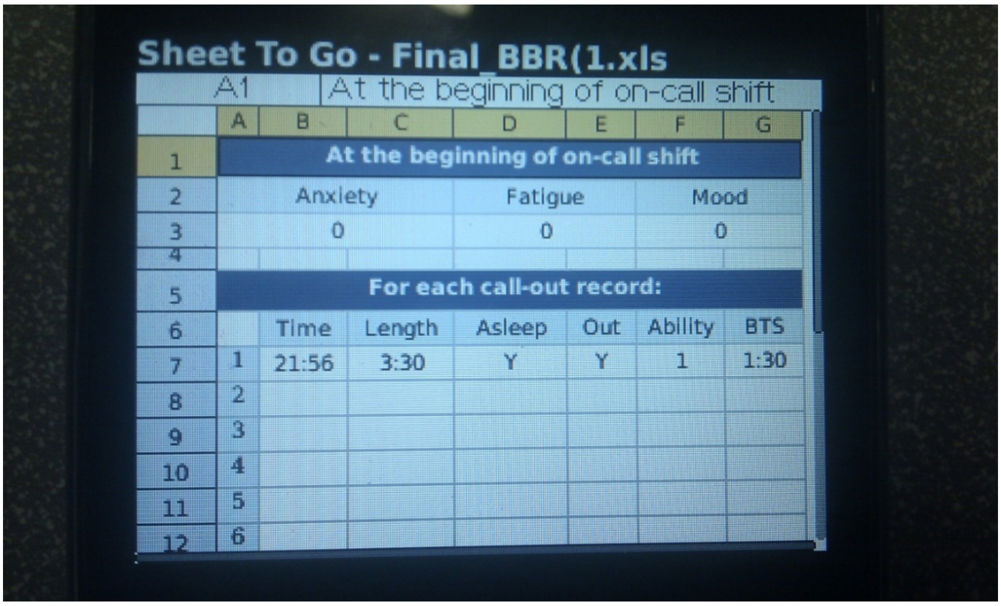


Figure 4.3 - Blackberry diary

4.7.2 Data capture

The data collection period ran from 5th March 2012 to 1st June 2012. Each participant was requested to maintain the diary for a period of two weeks, one week on-call and the following not on-call week. As each participant had its own on-call roster, and participants were scattered across GB, it could not be expected that each on-call week would coincide. The data was, therefore, collected at the time that each participant was on-call. It is accepted that such a procedure is vulnerable to a number of confounding variables but due to the nature of the on-call phenomenon, and the voluntary participation, these were unavoidable. Upon returning a completed questionnaire each participant was sent the instruction manual and the diary sheet and was invited to ask any question and to clarify any doubts they might have regarding the study. A small number of participants (four) did so but the majority seemed to have no issues regarding the instructions.

Recruitment for this study was done through Study 2 where at the end of the questionnaire survey participants were asked to participate in Study 3. As the data collected in the questionnaire was anonymous it was not possible to correspond the data of both studies. To collect demographic data a short questionnaire was included in Study 3 and was sent out before the beginning of the diary study itself. The demographic questions in this short questionnaire are identical to those used in Study 2.

Due to the geographical dispersion of the participants it was decided that diary completion instructions would be provided by email with the researcher making himself available to answer any questions that the participants could have before or during the duration of the study. Having decided which factors to explore, an initial set of questions was created based on the findings, and an initial version of the diary protocol was created together with an initial instruction manual. This initial version was assessed by five Human Factors practitioners from the Ergonomics team at Network Rail and an Ergonomics researcher at the University of Nottingham. The assessment focused on the overall arrangements of the question in the diary and the questionnaire, and the clarity and detail of the instructions manual. Several comments were returned both on the diary protocol and the instructions manual. The main comments were related to the clarity of the instructions manual and several recommendations were made with regards to wording, order of ideas, and with the representation of examples. Other comments were made on the overall arrangements of the diary and on its ease of use.

Based on these recommendations a second version of the diary protocol was created. In this version both the demographics questionnaire and the diary itself were made to look similar, the questions in the diary were re-arranged, and several changes were made to the instructions manual. At this point, a further three Human Factors practitioners from the Ergonomics team at Network Rail and an Ergonomics researcher at the University of Nottingham reviewed this version of the diary protocol. While the review identified a number of typographic errors and small mistakes, the diary protocol was deemed clear, concise, and easy to understand and complete. Having eliminated the typographic errors and mistakes found in the protocol, the final version of the instrument was created. Figure 4.4 shows a visual representation of the construction process of the instrument.

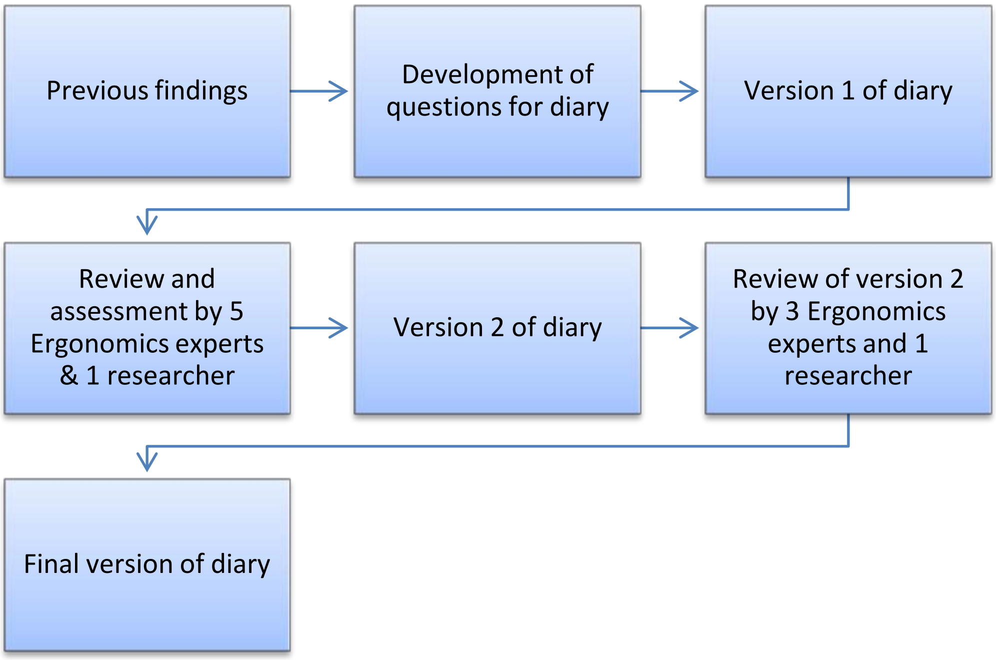


Figure 4.4 - Diary construction process

4.7.3 Implementation and delivery

All participants in Study 2 were invited to participate in Study 3. Once more participation was voluntary and from the initial 479 participants in Study 2 there were 148 who agreed to participate in Study 3. At the end of Study 2 all participants that volunteered to participate in Study 3 were contacted and informed that the data collection for Study 3 would start at the beginning of March 2012. Participants were informed that they would receive all details closer to that date. At the beginning of the study in mid February, all participants were contacted directly by email and asked to fill in the demographic questionnaire and to inform the researcher of when they would next work on-call. At this point 37 participants were willing to continue with the study and at the end of the data collection period 29 had completed the protocol.

4.7.4 Analysis approach

Similarly to Study 2, the data collected in Study 3 was also analysed through the use of both descriptive and multivariate statistics. Once more, the analysis was conducted using version 20 of the Statistical Package for Social Sciences (SPSS) and several multivariate statistical tests and models were used to analyse the data. The rating scales used to collect the data were also treated as interval in accordance to what was done in Study 2. Here also t-tests were used to explore the differences between on-call and off-call data and Analysis of Variance (ANOVA) tests and linear regressions were used to explore the differences between the different on-call scenarios, and to test hypotheses regarding which factors can be associated with the identified negative outcomes of working on-call.

4.8 Summary of research methods

This chapter discussed the research methods used through this thesis to explore the specific objectives presented in Chapter 1. The chapter described some of the methods that have been used to investigate both on-call work and shiftwork. The chapter then described the reasons behind the election of the methods used in this research. Due to the lack of understanding of on-call work it was decided to adopt an incremental approach in which the method of each study was based both on the results of the previous studies and the objectives of this thesis described in Chapter 1. The research framework presented in Figure 4.1. shows how these methods are structured and the aim of each one. The way each method was used to investigate the main research questions identified in Table 3.1 and to achieve the objectives of this thesis are exposed in a concise way in Table 4.5.

Table 4.5 - Summary of research questions and methods per research objective

	Research questions	Method
Objective 1	• What are the on-call arrangements and management procedures at Network Rail? • How do on-call workers feel about arrangements and management procedures?	• Semi- structured interviews • Questionnaire survey
Objective 2	• What are the main impacts of on-call work? • How do workers deal with these impacts?	• Semi- structured interviews • Questionnaire survey • Diary protocol
Objectives 3 and 4	• What are the on-call factors that lead to consequences and how do they interact? • What are the callout related factors that lead to unwanted consequences of on-call work?	• Semi- structured interviews • Questionnaire survey • Diary protocol
Objective 5	• How can the negative impact of the most damaging factors be reduced in Industry?	• Review of available literature • Semi- structured interviews • Questionnaire survey • Diary protocol

4.9 Chapter conclusion

Initial work conducted by the researcher at Network Rail identified on-call work as a topic of interest. Investigation into the available literature and working hours regulations further highlighted the need for research based knowledge to understand this working hours scheduling system. On-call work is not, at the moment, regulated and the available literature is very limited. Nonetheless, on-call research has identified a negative impact of on-call work and sleep quantity (Van Gelder & Kao, 2006), most likely due to anxiety about being awoken up by an alarm, or a callout (Torsvall & Akerstedt, 1988). Cognitive performance, mood, and well-being have also been found to have a negative association with on-call work (Eurofound, 2012; Heponiemi et al., 2008; Imbernon et al., 1993). Health related consequences have also been linked to on-call work, namely, stress, sleep, mental health, and personal safety (Nicol & Botterill, 2004). Other research, although not on-call focused, into the impacts of sleep fragmentation and sleep inertia, have also identified that sleep disruption has an effect on performance (Bonnet & Arand, 2003) and well-being (e.g. Goyal, Gay, & Lee, 2009). Sleep disruption and sleep inertia are two clear characteristics of on-call work. In addition, sleep disruption has been identified as a leading cause of fatigue by a large group of international scientists (Åkerstedt, 2000).

This chapter described the chosen methods to explore the objectives, and to answer the research questions, of this thesis. The application of each method was described and the results will be presented in the following three chapters where each of the three studies will be analysed in detail. The results of the final validation interviews are integrated into the discussion of the general results of this thesis and the conclusion chapter together with the recommendations produced.

Chapter 5 – Study 1: Semi-structured interviews

5.1 Chapter summary

This chapter discusses the first on-call specific research study conducted for this thesis. It details the preparation, execution, analysis, and results from semi-structured exploratory interviews conducted with NR on-call Infrastructure Maintenance staff. The chapter then describes the methodological implications derived from the findings of the study and concludes by presenting an iterated version of the initial framework presented at the end of Chapter 3.

5.2 Background

On-call work as the topic of research emerged from previous work conducted by the researcher at Network Rail. During the review of Network Rail's working hours management standard, it became clear that on-call managers were expected to be almost omniscient regarding the work being performed in their depot, regardless of the time when this work would take place. This work identified management and procedural issues regarding the on-call scheduling system of work. Further work investigating the safety behaviours of maintenance staff at Network Rail identified on-call as a cause of concern for some members of staff. This concern was later re-affirmed through fatigue management focused audits, where it was found that a great deal of pressure to perform was felt in Maintenance Depots where workers were expected to be available when they should be resting. These pressures, together with the apparent lack of awareness of senior managers of the processes and procedures in place locally, to manage on-call work led to the election of on-call work as the topics of this research.

On-call specific literature is very limited and the one that exists is lacking in descriptive information. Nonetheless, two different types of on-call work can be described, *proximal* on-call (worker in the workplace, e.g. doctors) and *distal* on-call (worker away from the workplace, e.g. rail workers). Moreover, European-wide research has shown that on-call work is quickly becoming the most common system of work in use (Eurofound, 2012). This is most likely due to it being a cheaper alternative to other types of work such as shiftwork. A number of associations have been found by researchers between on-call work and sleep, cognitive performance, and well-being indicators, such as mood, stress, and mental health.

A number of negative impacts of on-call work have been identified by research. For example, on-call work has been shown to have a deleterious effect on sleep quantity (Van Gelder & Kao, 2006) and sleep quality (Pilcher et al., 1997; Torsvall & Akerstedt, 1988), most likely due to anxiety about being woken by an alarm, or a callout (Torsvall & Akerstedt, 1988). This research has found that sleep disruption has a deleterious effect on performance (Bonnet & Arand, 2003) and well-being (e.g. Goyal, Gay, & Lee, 2009). Sleep disruption and sleep inertia are two clear characteristics of on-call work. In addition, sleep disruption has been identified as a leading cause of fatigue by a large group of international scientists (Åkerstedt, 2000). Not surprisingly, on-call work focused research has also found a negative association between on-call work and cognitive performance, mood, and well-being (Eurofound, 2012; Heponiemi et al., 2008; Imbernon et al., 1993). Health related consequences, although not being assessed by this work, have also been linked to on-call work, namely stress, mental health, and personal safety (Nicol & Botterill, 2004).

The lack of descriptive data is critical given some of the variables (such as timing of awakening, number of disruptions, and overall quantity of sleep) that can influence well-being and performance. All these make the outcomes of the two identified on-call working hours systems (*proximal* and *distal*) very different, and so might different on-call arrangements such as rostering arrangements (week/day) and length of on-call shift. In the rail industry on-call work is described as ‘waiting to respond to an emergency callout or answering a query from people working in the field’ (ORR, 2006). It was a system initially designed to ensure that in the event of emergencies, during the periods between shifts, there would be a number of qualified workers available to provide expert advice or resolve any faults that might occur in the infrastructure. This study aimed to allow the initial exploration of four of the five objectives of this thesis described in section 1.2 Aims and Objectives of Chapter 1, and to attempt to answer the research questions related with each objective described in Table 3.1 (Chapter 3) and replicated below.

	Research questions
Objective 1	• What are the on-call arrangements and management procedures at Network Rail? • How do on-call workers feel about arrangements and management procedures?
Objective 2	• What are the main impacts of on-call work? • How do workers deal with these impacts?
Objectives 3 and 4	• What are the on-call factors that lead to consequences and how do they interact? • What are the callout related factors that lead to unwanted consequences of on-call work?
Objective 5	• How can the negative impact of the most damaging factors be reduced in Industry?

At the start of this work, the researcher had little knowledge of the specifics associated with the planning and management of on-call work at NR. This also seemed to be the case across the organisation as there was no systematic information collected regardless of the existence of a general accepted view of what on-call work entails. Therefore, to allow both for familiarisation and to identify general relevant themes and issues relating to the on-call scheduling system of work, an exploratory, inductive approach was taken for the first study presented in this thesis. This approach used in-depth interviews, followed by theme-based analysis of transcripts.

5.3 Method

An interview script and protocol were prepared and reviewed to allow for an exploratory approach to investigating on-call working. Further details on the methodology used can be found in Chapter 4.

5.3.1 Selection method

Invitations to take part in the study and share their views regarding the on-call scheduling system of work were initially sent to each Delivery Unit Infrastructure Maintenance Delivery Manager who then cascaded the invitations down to their teams (see Appendix D – Interview invite). This approach was chosen both to keep the IMDM in the loop and as such facilitate participation and cooperation and because it was the most effective way of reaching frontline staff who don’t have email access. A non-probabilistic convenience sampling was used in this study since the only way to approach each Delivery Unit was to get in touch with the Infrastructure Maintenance Delivery Manager (IMDM), and request authorisation to invite their staff to participate in this study (Robson, 2002). Each member of staff working on-call was then invited to participate. The data collected reflects the views of those who were willing to participate in the research.

5.3.2 Sample description

From a total of 40 rail maintenance Delivery Units (DU), interviews were conducted at five DU. These covered all four levels of the on-call scheduling system of work in place at NR, with 71 members of staff, 54 of them of managerial grade. Table 5.1 shows the distribution of participants per DU and grade (i.e. Managerial or Frontline). All five of Network Rail infrastructure maintenance operational functions[6] were covered with 35 interviewees from the Permanent way, 19 from Signals and Telecommunications, six from Off-track, three from Electrification & Plant, and one from Telecommunications. The remaining three were high level senior managers, Infrastructure Maintenance Engineers (IME) and Infrastructure Maintenance Delivery Managers (IMDM) which sit above all the functions. The average age of the interviewees was 43 years of age (SD = 8.904) with the youngest being 23 and the oldest 59 years of age. Interviewees have worked in the rail industry for an average of 22 years, had been in their current position for an average of seven years, and had worked on-call for 11 years on average.

Table 5.1 - Participants per area and position

Area	Number of participants	Managerial	Frontline
A	15	11	4
B	8	6	2
C	16	13	3
D	19	14	5
E	13	10	3
Total	**71**	**54**	**17**

5.3.3 Interview procedure

Interviews were arranged to take place during three consecutive days so as to minimise the disruption of the day to day work at each Delivery Unit. During these three days interviews were conducted in accordance to the availability of the participants, any willing on-call worker that conducted on-call duties was interviewed. The interviews were conducted between the months of February and April 2011 in accordance to the dates made available by each IMDM. The interviews

[6]For details regarding NR Operational Functions see Table 2.3 in Chapter 2.

were composed of four separate parts: on-call arrangements, changes and impacts on personal life, issues and problems with the on-call scheduling system, and demographics. The complete interview script is shown in Table 4.1 (Chapter 4).

A quiet room in the maintenance depot was the only requirement made by the interviewer in order to conduct each interview. This was arranged in every depot where usually a meeting room was booked for the whole three days for the single use of the researcher. This allowed the interviewer the freedom to arrange the furniture in the room in a way that would better suit this type of interview. In accordance with interview techniques, obstacles between the interviewer and interviewee were removed and interviewees were invited to sit at 90 degrees to the interviewer and at a comfortable distance. With maintenance frontline staff spending most of their time out on track attending faults and conducting physical work, and even managers being required to be out on track frequently as part of their duties, the dress code at maintenance depots is casual. To increase rapport with both frontline workers and managerial staff the interviewer's dress code was prepared in advance to match the casual look seen in depots.

Having set the scene, each interview was then conducted individually. There were a few exceptions as six interviewees preferred to be interviewed together with a fellow worker that resulted in three paired interviews. All interviews were recorded using a dictaphone, amounting to 42h06mins of recording. In accordance to the procedure recommended by Robson, 2002, the interview was arranged as below.

1. Introduction: The interviewer introduced himself and explained the purpose of the interviews, assured confidentiality and asked for permission to audio record the interview and make notes.

2. Questions: Participants were asked a series of questions regarding the on-call scheduling system of work as described above.

3. Any other comments: The interviewees were given the opportunity to make any other comments that they felt were relevant to the topic and that had not been discussed.

4. Closure: The interviewer thanked the participant for their time and help.

5.3.4 Analysing the data

In accordance to the procedures of qualitative analysis it is recommended that several researchers work on the data and cross reference the data grouping and theme allocation with each other (Miles & Huberman, 1994). This was not possible and only the author worked on the project (with one exception discussed further below) and the inductive thematic analysis procedure was followed as presented below.

Stage 1: *Data Collection*. The method of collection was by individual, exploratory, semi-structured interviews with the exception of six interviewees who preferred to be interviewed in pairs. All data was recorded using a dictaphone.

Stage 2: *Preparation of data for analysis*. All interviews were integrally transcribed in preparation for analysis. Interviews from the first DU were transcribed by the researcher (approximately eight hours of audio), and the remaining interviews were outsourced to a professional transcribing company. Upon reception of the transcription all were verified individually for errors by the researcher before adding them to the data base. All recorded data was transcribed into text format using Microsoft Word then inserted into the qualitative analysis software package NVivo 9.

Stage 3: Theme definition and classification. Each transcription was initially read through and items of interest noted down and then sorted into proto-themes. Later these proto-themes were examined individually and an initial definition of each theme attempted. Each theme was then taken separately and each transcription re-examined carefully for relevant material.

Stage 4: High-order themes. Using all of the material relating to each theme, a final form for each was constructed with a name, definition and support data.

5.4 Results

Stage 3 of the analysis resulted in the creation of approximately 480 proto-themes which, during stage 4, were re-assessed and re-coded. These themes were then grouped into eight high-order themes with approximately 250 lower-order themes hierarchically arranged.

Given that one of the overall aims of this research was to develop an understating of the on-call scheduling system of work, high-order themes were organised in terms of the functions and characteristics of the work (e.g. On-call arrangements), rather than in terms of ergonomic concerns (e.g. fatigue). This allowed the researcher to schematise the idiosyncrasies of this system of work whilst also discussing how each different functional element of the system influences ergonomic constructs. Table 5.2 shows the order and description of high-order themes.

Table 5.2 - High-order themes

Theme number	Theme name	Description
1	General Attitudes	Details of the general feelings workers have towards on-call work
2	Stand-by	Details of events or feelings during the period of time when on-call but not receiving calls
3	Receiving callouts	Details of events or feelings when receiving callouts
4	Responding to callouts	Details of events or feelings when responding to callouts
5	Not on-call	Details regarding off-call work
6	On-call Arrangements	Details on the procedures and arrangements around on-call work
7	Management	Details on how on-call work is managed
8	Organisational Culture	Ideas and concepts that reflect the culture surrounding on-call work

The next section discussed each of these themes in turn. Sub-themes are presented under each high level theme in the order of frequency by which participants referred to the sub-theme (more frequent first). The exceptions to this are the sections of on-call scenarios themes (themes two, three and four) where the data is presented in accordance with temporal relationships. For example, when on *Stand-by* workers experience ‘anxiety’, which can then lead to reduced ‘quality and quantity of sleep’, which then leads to feelings of ‘fatigue’. Hence, these sub-themes were presented in terms of their assumed order of causality, rather than just in terms of frequency.

Finally, there is some replication of sub-themes across the analysis. For example, there might be general feelings of anxiety generated by the on-call system as a whole, as well a specific anxiety caused by the actual occurrence of a callout. Therefore, while there is some duplication of sub-themes across the analysis, the discussion and the model at the end of the chapter will attempt to synthesise these.

It is also important to remember that the data presented and discussed originated solely from the interviews conducted and represents the perceptions of those involved. It is possible that many of the management specific factors identified are not general across Network Rail and the rail industry as a whole. Furthermore, issues with on-call management practices should be expected across industries due to the lack of on-call research and knowledge paired with the lack of on-call specific regulation.

5.4.1 Theme 1: General Attitudes

This theme covers the different evaluations made by the interviewees regarding the on-call scheduling system of work and the reasons behind these feelings. Figure 5.1 shows a hierarchical visual representation of the lower-order themes associated with the high-order theme.

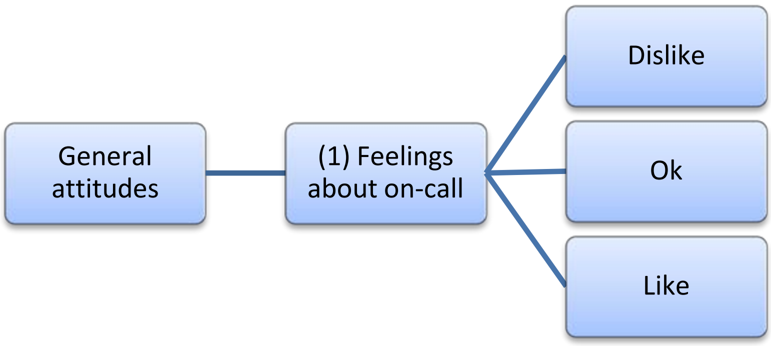


Figure 5.1 - General attitudes tree diagram

(1) Feelings about on-call

Interviewees attitudes towards the on-call scheduling system of work varied between tolerating it, ‘being ok’, and disliking it. There were 23 interviewees who stated a dislike for this system of work, (for example, “I hate it to be honest with you. It’s a big negative towards the job. If I could get out of doing it, I think almost every manager would”, P4) and would prefer not to have to work on-call, (e.g. “Given the choice not to do it, I’d not do it”, P33). There also seemed to exist a level of habituation to working on-call with at least 19 interviewees stating they are now used to on-call work regardless of the disruption it causes or their feelings about it, for example, “You become hardened to it, when you’ve been doing it for 25-30 years, it becomes a part of your life. After an amount of years it just becomes a part of life and you just accept it” (P35). Even so, at least 11 interviewees would be more satisfied with the on-call scheduling system of work if, like the frontline staff, they were paid extra for it (e.g. “I’d like to get paid for it. You know, some recompense for disruption to your family life and social life", P62). Managerial staff have been told on-call pay is 'part of their pay' but most, if not all interviewees, doubt this to be the case (e.g. "It is just part of your pay, yeah, the control managers are the same grade as myself, they are not on-call, but they are paid the same. Oh, you think, well, I don't earn anything for being on call", P71).

A similar number of interviewees (21 interviewees) stated on-call work is ok or not too bad (e.g. "It doesn't appeal to me; other flip of that I'm not adverse to it either", P29). The main reason for not disliking on-call is related to the number of callouts received, with these members of staff claiming the on-call scheduling system is 'ok' mainly due to not receiving many callouts, for example, "We are not getting many calls so it's not really affecting us. Not as if we're getting calls all night or up all night" (P17). Other reasons pointed out are the on-call roster frequency (e.g. Once every four weeks, for me, it's okay", P13), and from comparing their disruption level to that of other operational functions (e.g. To be honest is not that bad when you see the S&T SM, for instance, they have it a lot worse, so it's not so bad for me", P41).

There were only four interviewees that actually stated they like working on-call. One because in his previous post he was required to be reachable 24h a day, 365 days a year, as he worked alone, "Prior to taking this job as the assistant manager I was delivery manager for Area B, and that consisted of me and as many contractors as I wanted. I did one and a half years on call. This is a lot better", (P6). The others are young frontline staff who see on-call as a new experience and a chance to learn, for example, "It's exciting because you never know where you *gonna* be on a specific callout" (P40).

5.4.2 Theme 2: Stand-by

During the analysis, three on-call scenarios were repeatedly used by the interviewees to characterise the experience of working on-call. These reflect the three possible processes of working on-call and each of them can result in different outcomes. The next three themes discuss each of these scenarios separately. The scenarios are:

- Standing-by.
- Receiving callouts.
- Responding to callouts.

This theme discusses the on-call scenario when a member of staff is on-call but is not responding to calls and is in effect waiting for a callout or on *stand-by*. It discusses how this scenario affects the lives of the interviewees and the different ways interviewees use to deal with this situation. Figure 5.2 shows a hierarchical visual representation of the lower-order themes associated with the high-order theme Stand-by.

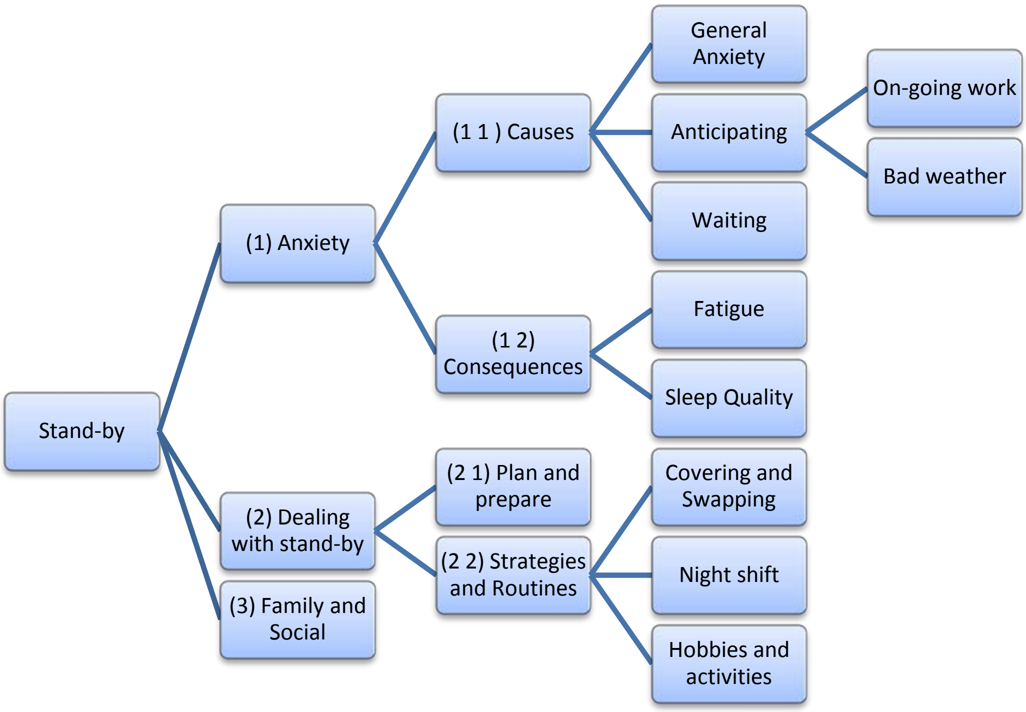


Figure 5.2 - Stand-by tree diagram

(1) Anxiety

The simple fact of being on-call without even being called-out can in itself bring feelings of stress and especially of anxiety to on-call staff. With 42 interviewees mentioning anxiety as a consequence of being on stand-by this is one of the most common feelings for on-call staff. The unpredictability of knowing when a callout will happen and the expectation of receiving a callout prevent workers from relaxing, for example, “It’s always in the back of my mind” (P30); “That feeling of anxiety is always in the background” (P24).

When probed for details regarding this feeling of anxiety interviewees put forward more specific themes that represent both the causes and consequences associated with this feeling of anxiety.

(1 1) Causes

When questioned for the reasons behind feeling anxious when on *stand-by* three reasons were put forward by the interviewees. These are *general anxiety, anticipating a callout,* and *waiting for a call* and these seem to reflect different degrees of expectation. Whilst general anxiety is a cause for anxiety without any specific triggers both *anticipating a callout* and *waiting for a callout* have specific triggers.

Of the three, the most common is general anxiety. For example, “You always feel at the back of your mind that somebody’s going to ring you up with a problem. You always have in the back of the mind you may get a phone call, because that’s what you’re there for” (P34), with 18 interviewees mentioning it as a key factor in the build-up of anxiety during their on-call period (e.g. It’s just the disturbing effect, because when you’re off from work, you can’t actually relax because you’re always expecting a phone call to come in”, P66). Furthermore, due to constantly worrying about being called-out, eight interviewees admitted constantly checking their telephones to make sure they didn’t miss a call or to keep informed of any possible issues that might escalate and end up requiring them to get involved (e.g. “You’re always on edge that you’re going to get a phone call. Especially when the reports come in through the Blackberry, they prime you to say this one could be big (delay minutes) you maybe need to start thinking about doing something or making phone calls. But when you don’t get anything you’re always thinking, ‘What’s the worst thing that could come in?” (P44).

The second most common reason mentioned by 11 interviewees behind the build-up of anxiety and the consequent inability to relax was the anticipation of a callout (e.g. “You are anticipating it I suppose, so you don’t relax as you do when you’re not on-call”, P9). Whilst *general anxiety* reflect the anxiety build-up simply from being on stand-by, *anticipating a call* is prompted by specific recognisable situations that had previously led to receiving a callout. *On-going jobs* for example, “If there are jobs on, obviously I’m at home and I kind of expect phone calls so there's some edginess” (P10) and *bad weather*[7] (e.g. “You can get anxious if you see that the weather is not looking good and you expect to get a callout”, P50) were the two specific situations

[7] Note: When discussing the reasons to be called-out in section 5.4.3 Theme 3: Receiving callouts bad weather shall be discussed again in more detail.

identified by the interviewees.

Usually when a managerial member of staff is called-out he is not required to physically attend the fault. Instead he might be required to maintain contact with the fault teams on the ground during specific points in time, or might be required to provide input if needed, so that he is in effect *waiting for a call.* For at least five workers this requirement creates even more uncertainty for the worker as he then does not know when, and how many times, he will be called again, for example, “It happens now and then that you get a call and then you have to say to the guys to call you when they finish and then you are lying in bed and thinking about it and you don't sleep or you have poor sleep and then you get the second call. It is the anxiety of waiting for the call” (P49).

From this data it is clear on-call work is characterised by a state of great uncertainty which in turn is a cause of anxiety for workers. The next section expands on the perceived consequences of anxiety and how the interviewees experience these effects.

(1 2) Consequences

Workers experience higher levels of fatigue (e.g. “If you’re going to have an on call arrangement it’s going to produce fatigue isn’t it, and a certain amount of stress”, P16). Fatigue build-up from working on-call was felt by at least 18[8] of the interviewees, they feel they suffer from fatigue due to the amount of stress that comes with being on stand-by (e.g. “Yes, fatigue I’d say, because what you find now is that you can’t go home and just switch off from work and separate it completely from your social life”, P66) and from the poorer quality of sleep they experience (e.g. “When I'm on-call I sleep less and am more tired - and still sleep less.”, P40).

As described before, on-call workers believe being on stand-by does not allow them to relax and ‘shut off’ from work. As a result they experience a disturbed sleep (e.g. “You can wake up and think, ‘Is that the phone?’”, P21) that is not restorative and leads to higher levels of fatigue. For example, “I’m a poor sleeper at the best of times and if you get called, you’ve had it. So normally even just the fact that you’re on call, I’m normally knackered by the end of an on-call week even if I don’t get any calls.

[8] When actually receiving callouts or attending faults the number of interviewees that feel fatigued rises considerably. For further details see the fatigue subsection of sections 5.4.3 Theme 3: Receiving callouts, and 5.4.4 Theme 4: Responding to callouts.

It's normally because when you're watching the pager you're dealing with it all. You don't switch off from work for 7 days" (P15).

Only a small number of interviewees (8 interviewees) stated they have coping mechanisms to deal with the impacts of on-call work. Of these, three state they cope with it by going to bed earlier during their on-call week (e.g. "You go to bed a lot earlier. Instead of staying up 10, 11 o'clock watching a film or something, I go to bed at 9 o'clock. I'm half expecting a phone call at 2 o'clock in the morning if I'm on-call. You're always expecting a phone call so I go to bed a lot earlier and don't go out", P32). The remaining five affirm they try to have a nap whenever possible: "Trying to catch up on sleep later on, power naps" (P34). It can be expected that these coping mechanisms are more common than indicated but might either not have been identified as specific behaviours by the interviewees or not be identified by them as specific to on-call.

A further eight participants believed there is a degree of habituation to the anxiety caused by on-call work and that after a period of time one gains more experience and is then able to relax more easily, for example, "Not so much these days actually. I used to not sleep very well when I was on call because it was constantly in the back of your mind that your phone might go, but I guess I've relaxed into it a bit now so I'm not worried about what I might get called about because I guess the worst has happened. I've dealt with lots of things so I don't worry about it" (P30). It is important to keep in mind that these workers do not claim they no longer experience anxiety but that they experience less or are better able to deal with it due to experience (e.g. "Years ago I was always on edge coz you didn't know when you were going to get a call - now you don't but at the end of on call you still go ahhhh (relief sound)", P47).

(2) Dealing with stand-by

On-call workers have developed a series of routines and strategies to better deal with being on stand-by. These take a variety of forms from personal management of on-call work, actual on-call arrangements, and supervisor and peer support.

(2 1) Planning and preparing

To deal with being on stand-by around a third of interviewees (25 interviewees) stated that they must plan their lives around their on-call work. Holidays are booked in advance to match off-call weeks and the same must be done for family or social events, for example, “You organise your life around it and your on-call, try and pick the weeks that you are not on-call, because it is just easier” (P63). The day to day life is also affected by on-call work with many staff refraining from social activities such as going out for dinner, or going to the cinema (e.g. “We tend to arrange our life, social life for going out, round on call because I know it could be a problem”, P56) as they might be called-out at any time.

Deciding to work the night shift during their on-call week was one of the discussed options on how to better deal with the on-call scheduling system. This option is not available to all members of staff but it is available to most, if not all, manager level staff and was explored by at least 15 of the manager level on-call staff interviewed. Due to the nature of the work managers are required to work nights on occasion. This is mainly to conduct inspections and, as such, many prefer to arrange their work so that their night shifts match their on-call week, for example, “Most of the calls are after hours, so, how we used to do it was that when we were on-call we’d decide to be on nights, because obviously we had to do our night shifts anyway. So it worked out well because if you’re on-call your sleep pattern’s interrupted anyway and that’s when you get the most phone calls” (P34). This system is advantageous because, as one is already up and working there is no risk of getting woken up by a callout nor does the callout disturb the partners’ sleep (e.g. “Always in when I’m on call, you don’t want to be lying in bed next to the wife and having her woke up or wake the kids up; so we always come in”, p7).

Choosing to work nights, however, does not solve the inherent problem of the on-call scheduling system of managing the day job. With workers choosing to work the night shift there may not be enough staff (8 interviewees) to run the depot during the day, for example, “The problem is that there is not enough of us to do that. During the working week generally requires two of us here anyway to deal with the mixed staff that we have. Any faults that are coming in – rostering requirements, we do everything for the staff we have got. So that is a two man job. If one of us said right I’m going to work nights when I’m on call, you know you would be pulling on the other one, be overloading the other one” (P29).

Another problem with this approach is that a traditional night shift starts at 23h and carries on until 07h the next day. The on-call shift, however, usually starts when the day shift terminates at around 16h. When choosing to work the night shift when on-call there is a seven hour gap that either has no on-call cover or forces either the on-call man or those working during the day to cover, for example “When you start a night, you are on-call, so say these guys, the section manager and all that, if I am on-call, all go home say 4, half past 4. So say I start 5 o’clock. Well, I can’t do, I can’t then work through to 7 o’clock the following morning, when they come back in” (P63). In addition, at least four interviewees dislike working nights or are not able to deal with rotating shifts (e.g. We’re not naturally nocturnal, and if you’re used to working days and you switch to nights, or do one night shift, it ruins me. So normally I’m hammered by Friday night”, P15).

The need to be prepared for their on-call shift was put forward by 11 interviewees. Preparedness is important so as to not be caught off guard and to be able to provide the fast highly quality response that is demanded of them when on-call. These preparations can be work related such as ensuring they possess all the necessary information regarding works in progress (e.g. “Remembering to have your blackberry with you, I have to have my laptop with me because it’s got all my information on that I might need. Some people carry manuals and stuff around with them so that they’ve got the information to hand”, P33). Or can be with regards to ensuring fitness to perform the on-call duties (e.g. “Usually instead of going to the gym or something like that I just sit home and try to relax, try to get my dinner a bit earlier so if I get called out I'm ok - save my energy“, P40).

(2 2) Strategies and Routines

The most common way mentioned by interviewees (49 interviewees) to deal with the intrusiveness of on-call work is to swap shifts with a co-worker or to get a co-worker to cover for a period of time. Workers are usually left to manage their on-call shifts and, as such, there is a high degree of flexibility about swapping shifts or arranging cover for either a whole on-call period (week usually) or just a few days or even for a few hours (e.g. “Well we’re flexible here, which is good. As long as I give them plenty of notice or they give me plenty of notice, we can swap things around”, P7). The reasons behind shift swapping are found in all aspects of personal life or work, for example, training, social events, family issues, holidays, and so on (e.g. “So yeah there’ll always be changes. Someone might go on a course. Somebody might be ill. Someone might need to take short term leave. Someone might just want to swap because they want to go out. So yeah, it’s quite common they’d be a change every week” (P68).

Another reason to swap or cover a shift for a co-worker is fatigue as it is recognised that after a few ‘bad’ nights working on-call one might not be able to deal with the workload anymore (e.g. “I covered last Sunday for the guy, who was, he had a particularly bad Friday and Saturday, so I had seen he’d done it so I said ‘Well, I’ll cover you during the day on Sunday’.”, P63). This freedom and flexibility to swap shifts when needed is also one of the reasons on-call workers are not very averse to on-call work (e.g. “It’s not like you’re on call seven days and you wouldn’t have no time off, you will be there, it’s not like that. So there’s a little bit of leeway sort of thing. You need to have a little bit of leeway, don’t you, if you’re on call all week or two weeks?” P1). When this option is not available on-call becomes more problematic. This can be due to lack of team member with whom to swap shifts (e.g. “There is no one to do it and that is the problem. This is, because you’ve got to have a certain level of experience and knowledge to do it for signalling, it’s not just as easy as saying ‘Oh, you come in at this weekend and do it’, P63), or a general unwillingness to swap due to the high workload, for example “We have here an unwillingness to cover each other’s on-call duty or annual leave, or sickness because we’re giving half an hour, 20 minute updates, it’s having a massive effect on your personal life and we’re not keen to cover each other’s on-call because of the hassle that comes with it”(P4).

Having and maintaining hobbies was presented by 16 interviewees as one of the most common ways of coping with the anxiety generated both by being on stand-by and general work related stress. Hobbies, interviewees feel, are also a good way to help maintain work-life balance, for example “I insist, even if I’m on call, I go to the gym. On a Wednesday is my night! I need a release from things by getting a sweat on and getting physical exercise, that’s how I manage it” (P15).

Another common strategy mentioned by 13 interviewees is to disconnect the email and text messaging functionality of their blackberries. This does not affect their stand-by as all callouts are conducted by telephone and prevents disruption. Due to current work arrangements, all fault messages are sent out to distribution lists and, as such, the number of emails regarding faults in one Delivery Unit or even the Route are send out to all members of the distribution list. This can result in an almost constant stream of emails. By turning this functionality off workers are able to reduce their disruption to only on-call related work (e.g. “All messages and all that, I don’t hear them anyway. The only thing I hear is if the phone rings when I go to bed of a night when I’m not on call. Even when I am on call, someone wants me they’ll have to ring me. I don’t look at messages during the night. You’d be on it every couple of minutes” (P35).

Another strategy put forward by a small number of interviewees (6 interviewees) is to sleep in a different room of the house so that if they do receive a callout their partner, and in some cases theirs children, do not get woken as well[9] (e.g. “The wife gets disturbed as well so I've actually taken to sleeping on the spare room when I'm on-call”, P46). In practical terms what this means is that together with the general strain of working on-call and having constant disruption to their sleep on-call staff might also be forced to sleep in a different room to avoid disturbing their families’ sleep also.

(3) Family and Social

Interviewees identified their family and social lives as the two major areas impacted by on-call work, with a minimum of 31 interviewees feeling that their family life is affected (e.g. “Obviously it disturbs me but obviously it disturbs family as well” (P64). However, the grand majority of interviewees (55 interviewees) feel the biggest impact is regarding social events (e.g. “The simple answer is yeah, social life is affected”, P6).

With such a high number of interviewees mentioning this impact to their social life this is perhaps the biggest area impacted by on-call work. The unpredictability of knowing when one will receive a call is paralysing and many workers decide it is not worth risking being disrupted in a restaurant, the cinema, or any other social event. Due to this, at least 39 interviewees choose not to participate in some, or all social events, whilst on-call (e.g. “Social life… you don’t have one for the week while you’re on call. You write it off because you need to be contactable straight away, and the last thing you want is to be half way through a meal in a nice restaurant, your phone goes off, and you go outside so you can take the phone call. You then go back in and go, ‘sorry love, you make your own way back, I’ve got to nip into work’. So I

[9] Further details are explored in section 5.4.3 Theme 3: Receiving callouts.

think a lot of us accept that when you're on call, it's just purely you do on call". P6). For a smaller number of interviewees (21 interviewees) although on-call is disturbing they still try to maintain their 'normal' life and keep planning and attending social events by swapping or asking a co-worker to cover that shift (e.g. "It doesn't stop me doing anything. If I plan to go out for a meal, I'm going out for a meal. If a party comes up, I would get somebody to cover it for me because that's part of the teamwork", P48). When not able or willing to swap, workers also choose to risk being called-out half way through their event (e.g. "Well obviously my wife's aware that I am on call and it's a chance we take. If I have to go, you know, and cut short my dinner reservation then that's what I'll do. It's something I myself think, well, I don't want to put my life on hold, because I may not be called out. But I do explain to my wife if it happens then I have to go and it's just the way it is", P5).

Network Rail operates a zero alcohol policy so during the on-call period staff are not allowed to drink. For at least 28 interviewees the impossibility of having a drink whilst working on-call is an important area of their social life that is affected by working on-call (e.g. "You haven't got to go to the pub to watch football, you go to the garden on a nice summer's evening, have a drink, but as soon as you have a drink the phone will be going – so that's how it affects your social life", P14). The callout response time (amount of time allowed to respond to a callout) and the potential need to attend faults restrict the movements of on-call works. This poses a problem for at least 23 interviews who state they are unable to travel outside their coverage area when on-call (e.g. "You can't really go out can you. You have to be at home, don't you? You have to be somewhere where you can, if you get called out, you have to go back to work, if you can't get hold of your team or someone you have to attend" (P32). The impact of this is mainly felt during days off when still working on-call and is mainly felt by the on-call response level employees that are always required to go out and attend the fault (15).

Furthermore, for some interviewees on-call work is a source of conflict with their partner. At least 21 interviewees declared their partners were not happy at all with their on-call scheduling system of work (e.g. "It does make it quite difficult, because I have got three young children, and my wife doesn't like me being on call. 'What is more important, me or Network rail?' or this, that and the other. It has started arguments in the past", P60). Around half of them (11 interviewees), however, also believe their partners are now used to it and that there is also a degree of acceptance by their partners (e.g. “The wife is used to it, you do get the odd comment ‘are you going back in?!’ but she's used to it” (P38).

A number of interviewees feel on-call has a specific impact in the amount of free time they will have to spend with their children. This is an issue for at least nine interviewees that feel the amount of time and the range of activities they can perform with their children is limited, for example, “This last time I was off on Thursday, Friday, Saturday and Monday, I was on-call and I actually didn't get a call but I took the boys swimming on Friday and half way through I had to go because I didn't wanted to be missing calls” (P46).

5.4.3 Theme 3: Receiving callouts

When called-out on-call staff are required to either physically attend a fault or to be consulted over the telephone for expert advice. For managerial level staff most callouts do not require them to attend the fault physically but to provide advice over the telephone. For frontline staff the opposite is true and, as such, in most situations each callout requires them to physically attend a fault and carry out repairs.

This theme discusses the on-call scenario when a member of staff is on-call and is receiving callouts but is not required to attend the fault physically. It discusses the perceived impacts of this scenario and the different ways on how interviewees deal with this situation. Figure 5.3 shows a hierarchical visual representation of the lower-order themes associated with the high-order theme *Receiving callouts*.

Figure 5.3 - Receiving callouts tree diagram

(1) Sleep Disruption

After receiving a callout, and taking all possible actions to minimise the disruption to other members of the family, the on-call worker must then ensure he or she is able to deal with the call. This is problematic, and most interviewees (19 interviewees) state they require a period of time to wake up and prepare themselves to take the call (e.g. "I tend to obviously get my head around, who has rung me, and say I will ring them back and then I will obviously creep, I will get my books out, it takes me about fifteen, twenty minutes to wake up. I can't just wake up like that and just answer it. That is if I hear it. But yes, I'm not straight away on the ball, no. I don't think anyone would be. Not at two o'clock", P8). Only three interviewees stated they are immediately awake and ready to deal with work, for example, "Not saying it's an adrenaline rush but once you get a call you know there's something on, you do wake up, you get pumped up, but then sometimes it's nothing" (P22).

After dealing with the callout many interviewees (37 interviewees) find it difficult to fall back a sleep (e.g. “You’re wide awake by the time you’ve gone downstairs, so it does take an hour or so to get back to sleep, P23). However, there are a small number of interviewees (13 interviewees) that do not find it problematic (e.g. “I’ve always done this type of work, so it’s always been get sleep when you can”, P34). Worrying about the decision made or advice given is the most common reason for this difficulty with 18 interviewees stating they are unable to fall back asleep due to worrying (e.g. “The trouble is as well, once you’ve been called, it’s the being able to get back to sleep again. Because when you’ve gone through it, you’ve written down, you’ve made your decision; I’ll then sit and think about it after I’ve put the phone down. And there’s been a couple of occasions where I’ve called someone back and go I just want to make sure I was clear, I can’t quite remember how clear I was with you. And just confirm, because otherwise I just can’t get back to sleep. And I do worry about things so I want to make that you’ve said the right thing; you’ve done the right thing”, P30).

The level of disruption from each callout, for 20 interviewees, is dependent on the length and timing of the call with longer calls being more disruptive, for example “The ease of getting back to sleep depends on what the call is, you can be on the phone for 5mins or for hours. If you are up for a couple of hours you find it very hard to get back to sleep” (P49). Regarding the more disruptive time to get a callout no pattern was identified, with 10 interviewees feeling that it is more disruptive to be called out in the first few hours of sleep (e.g. “As I say, we go to bed what 10:30-11:00 so if you’ve been disturbed at 11:30, then I think it has a bigger effect on me, because I’ve gone into the deep sleep mode. You’re then being woken up, whereas if somebody wakes me up at, I don’t know, 4:00 or 5:00 in the morning, then I’m an early bird anyways, so 4:00 in the morning, I’ll be wide awake”, P64). The other 10 interviewees feel the opposite is true (e.g. ”If it is about 4, half past, it is not easy because my body is ready to get up anyway, because I am up at quarter past 5 anyway. So you are in that light phase of your sleep, not in your deep sleep”, P28). For seven interviewees the time of the callout is not a reason for fatigue build-up at all. These feel that independently of the time of the callout their rest is disturbed to a point in which they are unable to rest enough to feel refreshed in the morning (e.g. “Even one call in the middle of the night, your next day is destroyed”, P69).

Receiving multiple callouts was only mentioned as the biggest impediment to falling back a sleep by three interviewees (e.g. " It's alright for the first couple and then it gets harder and you end up being wide awake. If I get a call and it's a quick call I can probably go back to sleep straight away. Someone rings you again 20 minutes later it tends to wake you up and it'll take you an hour or so to get back to sleep. It depends on how many calls", P39). The researcher expects this to be one of the more disturbing factors of on-call work and its low frequency could be due to most on-call staff not receiving multiple callouts very often or that for many on-call workers a single call is in itself very disruptive[10].

When asked about strategies to fall back asleep after a callout, the great majority of interviewees who admitted having troubles falling back asleep (10 interviewees) stated they simply lie in bed and try to fall asleep (e.g. "I just go back to bed and toss and tumble until you get back to sleep", P45). When unable to fall back asleep at a time close to their usual time for getting out of bed, at least six interviewees state they prefer to get up and go to work (e.g. "I normally get up about half 5, so you get a call at 3, you know you're not going to get back to sleep, you'll start making moves to get ready and you'll end up coming into work early", P44). Reading and watching television were the only two strategies mention by eight of the interviewees to help them relax and fall back asleep (e.g. "I always try and read to try and relax my brain and fall asleep. I tend to find I get through my reading [laughter], I tend to read a lot more when I'm on-call", P65).

(2) Family and Social

When receiving a callout after bed time there is an immediate impact on the on-call worker as his sleep is interrupted. Not surprisingly, this disruption extends to the on-call worker's partner with at least 34 interviewees stating their partners are woken up as well with the callout. Moreover, eight of them also stated their children also wake up, for example, "It'll wake the household up if the phone goes off and of course, you have got to get dressed, get the van off the drive and go to work in the middle of the night so yes, they are going to wake up with you nine times out of ten" (P21). To ensure their partners are disrupted as little as possible when receiving a callout at least 16 interviewees choose to leave the room as fast as possible (e.g. "Grab the

[10] See subsection (4) Calls in this section for details regarding callout frequency.

phone, I go into the bathroom on the phone so I don't wake up the Mrs", P57).

When being called-out during non-sleeping hours, interruption to family or social activities is the main impact felt by workers as they are then forced to respond to the callout, for example "I go canoeing and the amount of times I'm dealing with stuff on the canoe, so we'd be canoeing and all the family are in it and all of sudden the phone will go and I'll have to stop paddling and deal with something on the phone and just leave it to everybody else, that's happened several times" (P65). Additionally, this reduces the quality and quantity of time on-call staff have with their family (e.g. "It affects the quality of the time you are with your family, you will be at home, but you'll be on the phone. So, you are sort of at home, but you are not, if that makes sense. You are there but your focus is on something else, if that sort of makes sense. You are there, but you are not when you are on-call", P69).

(3) Fatigue

As a result of being disrupted in their sleep and as consequence of reduced quantity and quality of sleep when receiving callouts, at least 32 interviewees feel more fatigued when working on-call when compared to not working on-call, (e.g. "I think it just makes you much more tired and you can feel you really need a break after a week on call if you've had a bad week and just disturbs your sleep", P30). Feeling fatigued the day after receiving a callout is a reality for 24 interviewees that see on-call as a cause of fatigue on the day following the disruption (e.g. " If you get a call late at night or during the early hours it definitely affects you, you feel tired and I think it can affect your job the next day too, it just feels like it's a long day", P41).

For at least 11 interviewees these effects are of a cumulative nature and as such are felt through the on-call week and keep getting stronger towards the end of the week, for example "I would say if it runs maybe 2 nights where you're getting that level of disruption you definitely feel it towards the end of the week. By the time Friday comes you're just desperate to get out of call and get away and get a sleep, couple of pints of beer in you, you're out cold" (P44). Much the same as with regards to sleep disruption, the effects of on fatigue are also felt by the on-call worker's partner with nine interviewees stating their partners also feel more tired during the on-call period (e.g. "If I've had calls and she's been woken up in the night she might say to me the next day, 'I'm tired,' she goes, 'all those blinking calls last night', so yeah, she'll try and have an early night if she can too", P65).

In accordance with current NR fatigue regulations workers must be given 12 hours rest after a callout[11]. For most frontline staff this regulation is followed and after being called-out each member of staff is then given 12 hours rest from the point in which they close the fault for which they were called-out for. For most managers (32 interviewees), who are responsible for managing their own hours, this rest is often not taken as most arrangements and meetings must be dealt with during the day, for example "I've got a few calls at 2am and still be out on track at 11 o'clock then you have to come in the office and trying to get the day's work done. We're working on short staff so you have to do it to try and catch up", P51). Managers may instead, as stated by 27 interviewees, choose to have a late start in the morning or leave earlier in the day when possible to help deal with the tiredness (e.g. "If you're too tired you have to phone up and say 'I'll be in later on'", P34). In the event of a particularly difficult on-call shift at least 12 managers admitted to taking a day off to rest (e.g. "If there's nothing important the next day, you know desperately important; I might have the day off. If there's a meeting in first thing in the morning, I feel this is really important, I might come in for that, do that and then go", P56).

(4) Calls

According to 43 interviewees the amount and duration of received calls when on-call, and of any work carried out as a consequence, vary too much for patterns to be clearly identified, for example "I couldn't say there is any pattern to it. Some weeks you can go without a single call and other weeks you are out every single day, twice a day" (P24). A good week could have none or very few calls and a bad week can reach twenty calls plus (e.g. "In a good week your phone might go once or twice a week and maybe once or twice per fault as well. On other weeks is constant, every night you get a call", P45). It is important to realise that what is considered as a bad week for some may be considered as a good week for others, for example "I've dealt with, in the past, 20, 30 phone calls a night, some nights" (P62), versus for example "A bad week I imagine you could classify as five calls plus" (P7).

The length of each callout also varies greatly with managers' calls ranging from five minutes to a several hours (e.g. "It depends what the problem is. It can be a 5 minute

---

[11] See Chapter 2 – Section 2.5 Regulations for details.

phone call or several phone calls. It can be all night”, P34). For frontline, who are almost always required to attend, a callout can range from three hours to full shifts (e.g. “Last time I was called out was when I was last on call actually, I was out for nine hours”, P19). Moreover, as mentioned before, it is not just the amount of calls and their duration that is problematic, as any one single call can prevent rest for several hours due to worrying about the decision made, or the advice given, or simply because one might need to get or give updates at regular intervals. Without the knowledge of specific number of calls received it is impossible to draw any conclusions regarding how disruptive a certain number of calls or the timing when they occur can be.

Similarly to the results found when discussing anxiety levels, on-going jobs and extreme weather are here also pointed out as the main causes of having a high volume of callouts, for example “It is season dependant too, in the summer you get more calls. There is definitely a seasonal variation. And also in the winter because of the snow and the cold, you get more callouts - this year with the bad weather I got more callouts than ever but before that it is usually worse in the summer. It's the extremes really” (P52). Likewise the amount and duration of calls, 24 interviewees also found the timing of calls to be unpredictable with callouts occurring at all hours during their on-call period (e.g. “No pattern, it’s just whenever. It’s the nature of faults, when something fails”, P39). There were, nonetheless, two patterns identified. One from the beginning of the on-call shift until the start of the night shift (around 23h) as from then shiftworkers can deal with the faults instead of relying on on-call staff (e.g. “Calls will usually be between 16h and 23h as calls after that will be picked up by the night shift instead”, P40). The second, at the start and finishing times of possessions (around 00h and around 05h). A possession is the disconnecting of a section of track form the network so that maintenance work or network upgrades can be conducted on that section. For example “Majority of the phone calls will be in the evening and up to around one o’clock, two in the morning because that’s when possessions are taken and the night shift starts so they go through their paper work and everything.” (P29).

(5) Reasons to be called-out

The on-call scheduling system of work was initially designed so that in the event of emergencies an expert would be available to provide guidance on resolving faults.

Some interviewees (9 interviewees) feel this has changed in recent years and on-call work now seems to be used much more as a cheap alternative to shiftwork (e.g. "It's got progressively more and more and more intrusive in terms of, well, your life outside of work. Whereas we started off, we would only be involved in what we class as wrong-side failures and major incidents but now it almost feels as if a sparrow farts on the track, you know, we will get a phone call", P69). All callouts originate from fault control (a 24/7 manned Network Rail department that monitors the track and reports and logs faults), but during the resolution of a fault information may need to be exchanged between a frontline team and a manager, between different teams and different departments.

For managerial on-call staff the list of issues that warrant the input of on-call workers is long and varied (e.g. "Technical issues, remedy – system of work issues, and staff issues really, paperwork, safe system of work issues, signallers refusing to ground their occupations or somebody that goes sick and they haven't got enough men to do the job", P29). The reasons to be called-out for encase a very large number of management related issues, such as, approval of procedures, to coordinate work, to grant permission to conduct specific work, amongst others.

Due to the on-call levels system, the most commonly mentioned reasons to be called-out for managerial level workers are to provide advice and guidance (e.g. "If they can't handle it, if it's outside their scope of responsibilities then they ring us for guidance", P32), and to make decisions and manage processes (e.g. " Verifying people's decisions, helping them with the decisions, making decisions – decision making. Knowing what the incident is, getting people to report back to you, making sure you're keeping documentation and authorising the equipment back into work once the incident's over", P31). Manager level callouts are usually required to deal with serious faults as the simpler faults should not require higher level input (e.g. " It tends to be the more serious stuff that we get a call for", P64).

There are also a high number of calls that 25 managerial level interviewees call 'silly calls' or calls that are not justifiable. These are calls the interviewees feel the caller should know the answer to its own question, calls passing irrelevant information, or calls that are not urgent or 'could wait until the morning'. These can be both from Fault Control, for example "With control you get all manner of courtesy calls now. They will phone you as their level 2 during the nights just as a courtesy call to tell you that something has happened. And you think well, where is the fault team? ‘Oh, they are dealing with x, y and z.’, ‘So why are you phoning me?’” (P2), or from the frontline teams (e.g. “Getting phoned up in the middle of the night, asked for someone’s phone number which has happened to me loads of times. Somebody on the site would ring me up and say, ‘You haven’t got the phone number for so-and-so?’ and all this sort of stuff and the favourite one is you’ll get someone ring you up and say, ‘I didn’t wake you up did I?’, ‘Oh no, I’m up at three o’clock!’”, P58). The frequency of these ‘silly calls’ ranges from around 20% for some managers to 80% of all calls for others. For those managers that stated they received very few such calls, the reason pointed was the self sufficiency of their teams (e.g. “I think it’s as much down to the men you’ve got working for you and with you as to how well it works”, P66). Many of these calls seem to originate from Fault Control so other factors must also be in play although it is not possible for the researcher to speculate on based on the information collected.

Much the same as for managerial levels of on-call, the reasons to be called-out for frontline are several, dependant of each operational function, and cover any possible fault that might occur on track (e.g. “With our industry it can be anything, whatever fault comes in”, P5). The quality of the track was identified as the one key element responsible for reducing the number of callouts frontline staff receive (e.g. “It has been common but at the moment it’s calmed down because a lot of our rails have been changed so the defects have gradually decreased over the years. We did have a tremendous amount of defects come in but now they’re gradually getting less, so getting called out is less”, P32).

For at least 24 interviewees, of both frontline and managerial level, the need to constantly send or receive updates regarding the resolution of a fault to a large number of stakeholders is possibly the biggest cause of disruption associated with the current arrangements of on-call work (e.g. “Thursday night and they guys are out so they are due to start at midnight and at 12:05 I had a phone call for that night and it was like ‘oh, we are having problems here’). And they are just keeping me informed but I know the job has got to be done so I have got to be sort of, on the ball to try and make a few phone calls if needed and maybe even go out on site if needed. But in the end it was all right, they managed to sort it out without me being there but they kept – I had about three or four phone calls in the night just keeping me up to date with any problems", P10). The requirement to send out updates is not part of general on-call management procedures and as most on-call related procedures seems to be managed locally.

Not only can these updates be disrupting to sleeping on-call managers but they can also disturb the fault teams that are rectifying the fault. For some interviewees this requirement to send out updates is partly driven by changes to Fault Control[12] and driven by senior maintenance managers that, due to their eagerness to have the fault resolved, bypass the on-call scheduling system altogether and get involved in each fault[13] (e.g. "We're also required to provide Control 30 minute updates. So from a supervisor's point of view it's every 20 minutes you're on the phone, getting an update from the technicians to give Control an update. Control as well as the Route Director and the IME as well as the IMDM and every other man and his dog who just likes to get involved at that time. It's usually by e-mail but normally higher up get impatient so they're ringing you anyway. And then you're e-mailing as well. And so we have to ring the technicians who are on site every 20 minutes which basically prolongs the failure, in my opinion, increases delay, and it causes unnecessary cost. Just so we can update people upstairs", P4).

(6) Performance and Mood

When receiving callouts at least 11 interviewees feel their ability to perform their jobs is affected both during the callout, for example "I don't think we are competent to make safety critical decisions in the middle of the night" (P4), and during the next day or days (e.g. "You can't think as clearly, you're not as productive, and to be honest you can't spend as long in work. The job demands long hours because of the amount of work you've got but normally you go home earlier because it's pointless being in work trying to do work because you're in a fog", P15). Sleep disruption from receiving callouts and the subsequent fatigue can also cause mood changes with at least 5 of the interviewees feeling their mood is degraded (e.g. "You get grouchy when you're tired. Yeah, I'm cranky. You know, if I'm doing something at work and somebody comes up and wants something, you tend to snap a bit and then you have

[12] For details on changes to Fault Control and how this affects the on-call scheduling system of work see subsection (4) Alternatives of section 5.4.6 Themes 6, 7 & 8: On-call arrangements, Management of on-call work, & Organisational culture.

[13] The bypassing of the on-call hierarchy is discussed with more detail in subsection (1 6) Micro management and by-passing the on-call scheduling system of section 5.4.6 Themes 6, 7 & 8: On-call arrangements, Management of on-call work, & Organisational culture

to go back and apologise", P62).

5.4.4 Theme 4: Responding to callouts

This theme discusses the on-call scenario when a member of staff is on-call, is receiving callouts and is required to attend the fault physically. It discusses the frequency and reasons to attend a fault and the perceived impacts of this scenario. Figure 5.4 shows a hierarchical visual representation of the lower-order themes associated with the high-order theme 'Responding to callouts'.

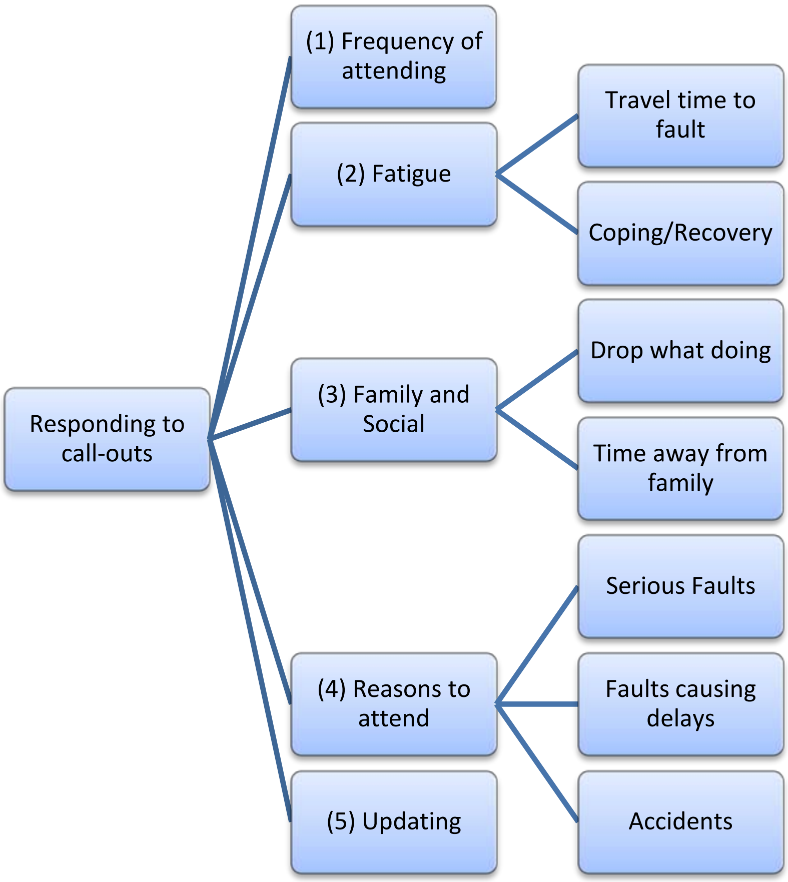


Figure 5.4 - Responding to callouts tree diagram

(1) Frequency of attending

For frontline staff each callout requires them to physically attend the fault whilst for managers this will only happen when there is indeed a requirement for them to do so. Interviewees were unable to quantify how common it is for them to be required to respond to a callout by attending the site with 23 interviewees stating it varies greatly (e.g. “It varies to be honest. You can’t actually put a number on it. I’ve done, where I’ve been out, ten times in a week and yet I’ve done another occasion where I haven’t had to leave home”, P6). Independently of the variance of frequency of attending the fault physically, at least 18 managerial level on-call interviewees agree that it is not a common event, for example “It's not usual for me to go out - not even 1 in 10 calls I need to go out” (P41). Nonetheless, a great variation was found across all interviewees with the more senior managerial on-call staff only being required to attend a few times a year, for example “Maybe once or twice in a year” (P17), and less senior managerial on-call staff attending more frequently, for example “Actual calls that I have to attend where I have to leave the actual house that would be one, for every week of on call, on average” (P29).

(2) Fatigue

Feeling fatigued from responding to callouts is common for at least 21 interviewees (e.g. “You can only do so many hours a week and suddenly you lose your ability to function properly”, P58). One of the reasons to feel fatigued, both for both frontline and managerial on-call staff, is due to driving to and from site and which carries the risk of falling asleep whilst driving (e.g. ”The driving can get quite difficult and quite scary, so to speak. Quite a few times I have been driving on the road and have got tunnel vision sort of thing so no, I don’t think it’s a safe way to do it [on-call work]”, P21). As 17 interviewees put it, this is mainly due to the distance and as such the time necessary to get to and from the fault site, for example , “I live around an hour’s drive from the depot but when we are on-call we cover a large area so we can be going anywhere - the furthest point would be 3.5h hours” (P51). As will be discussed in more detail in section 5.4.6 Themes 6, 7 & 8: On-call arrangements, Management of on-call work, & Organisational culture, on-call areas are much bigger than the areas covered by each depot which in turn means that the time needed to get to and from faults can be very high.

For managers, fatigue is mainly felt during the day after the callout, with at least 12 managers stating they will feel more fatigued than when just receiving callouts (and not actually attending faults), for example “The worst thing is the tiredness. You are absolutely knackered. And then your boss is trying to get you to go out to site. So you have done your day’s shift, you’ve done, you know, I would do say 7 till 4, 6 to 4 or whatever I have done and then you’ll get a failure kick off in the evening and you are sort of encouraged to go out. I’ve only had like 3 or 4 hours off and then you are expected to work a night turn as well, so it does become, on a bad week it is bad, it is bad”, P63).

Frontline staff are given 12h rest after being called-out making next day fatigue less of an issue, but the constant shift between day and night shifts will also take its toll, for example, “It can (affect your fatigue levels) if you have had a heavy week because if are doing your normal shift then you go home and after a couple of hours are called out again, and then you have your 12h rest then you are back out a again, and then you can go out again” (P50).

To recover from this fatigue most workers state they require only a couple of days rest (e.g. “It does take you a few days to get to normality. It affects you”, P26). However, this is not always possible due to work arrangements and the on-call scheduling system itself where staff can be called-out again the following night.

(3) Family and Social

When responding to a call, on top of the interruption already caused to their social and family lives (see section 5.4.3 Theme 3: Receiving callouts), at least 16 interviewees feel a further impact when they are then also required to drop what they are doing to attend a fault (e.g. “You take your wife out for a meal and your phone can go and you have to leave her”, P45). Furthermore, being called-out to attend a fault additionally prevents workers from spending time with their families, for example, “If you got a callout you’re not with your family so you’re missing out on family life” (P26). This is specifically an issue for frontline staff with children as they are almost always required to attend the fault and as such spend longer periods of time out of the house (e.g. “When my children were young, they fought with it, that dad was off sorting out here and there and everywhere, this time, that time, anytime”, P62).

(4) Reasons to attend

On-call workers at different on-call levels will be called-out in accordance to the seriousness of the fault, with the more senior staff will only be called-out for very serious faults. For managers only ‘serious faults’ require them to attend a fault on site as described by 15 interviewees (e.g. “If the fault has a high risk then we are expected to be on site but sometimes it just makes it easier to go out”, P46). The criteria of what qualifies as serious faults and the criteria to calling-out more senior on-call staff are, however, diverse and vary from team to team. So, once more, the on-all system is subject to local management practices and no clear guidelines or rules seem to be in place to decide when to involve different on-call staff.

Managers also feel they need to attend differently and for different issues, for example "Everyone is different; some people try and do it over the phone instead of actually going to site. I've seen managers going on to site just because they were called. Maybe they thought they had to or it was an important issue for them" (P43). The list of faults managers will choose to attend is not set and different managers will attend different faults with some attending callouts regarding 'animals on track' (9 interviewees) or 'bumpy rides' (7 interviewees), whilst other will not (e.g. "This is what I decide to attend. Some of the other supervisors might be different. Some of them might not feel they want to go at all. They might have a track charge man they can trust and they rely on them", P7).

For nine managerial level on-call interviewees faults causing delays are the most common reason to attend a fault for example "You'd go out and be expected to take the lead during a major failure or a failure that's causing a lot of train delays" (P27). Significantly, all nine interviewees are part of the S&T operational function and this requirement is associated with the Asset Recovery Manager (ARM) role. Whoever is assigned to the role of ARM is made responsible for resolving the fault and in effect brings the asset to its full use again. This means that the manager that is assigned to be the ARM will need to be involved throughout the resolution of the fault, coordinating the work of different teams, different departments, and providing regular updates to both control and many other stakeholders, for example, "It's not so much a technical role, but it is a gathering information and reporting back to everybody and managing the failure, which is not necessarily a particularly technical role" (P3). In practice it is the first on-call managerial level that will usually be nominated to perform this role.

In theory an ARM should only be appointed when a fault is likely to exceed 500 minutes of train delay[14] but, in accordance with some interviewees, these limits are no longer being respected and on-call staff is being assigned this role more and more

[14] The way the GB railways are organized means that when infrastructure related faults cause delays NR is required to pay the train operating companies compensation per minute of delay.

frequently for example “The IMDM says we should only be nominated if the delay is likely to exceed 500 minutes of train delay but now the default situation is “it is going to be bad, we need an ARM” (P2).

The main problem with this role being assigned to the person on-call is that there will be no one else available to take over if and when the person on-call is too fatigued to carry on. This in practice means that the person on-call will not stop working on the fault until the start of the next shift, so if the manager is assigned to be the ARM straight after the end of the shift he or she can potentially be working non-stop for 24h, for example “There is always that risk if you are the on-call man. There is nobody else to do it, and everybody else who could hand over to has all been working all day as well. So you are really left with no option, because there is nobody else to hand over to” (P2). The role of ARM is a specific role within S&T but all the same risks are present for the other operational functions. The difference being that managers are given more freedom to manage their on-call working hours and as such to better manage their fatigue levels and rest.

Furthermore, for at least six S&T managerial on-call staff there is also the perception that there is now an augmented expectation to physically attend the fault (e.g. “Now there is more influence and more direction now for 2nd on-call to go out to site” P49). This is, once more, due to the role of the ARM.

Staff accidents were also mentioned as a reason to attend faults. These were mentioned by eight interviewees as, when they occur, the on-call manager is required to lead the investigation into the causes of the accident, for example, “If there is an accident we are expected to go. If somebody says they’ve cut their hand on a gate or they’ve slipped it’s mandatory that we attend for interviewing the guy, taking photos” (P16).

(5) Updating

Much the same as discussed with regards to receiving callouts, the need to constantly update stakeholders is an issue for at least 8 on-call managerial level interviewees when on site (e.g. ”We are constantly having to send out updates via email to loads of people”, P63). In the same way as when updating the stakeholder from home, workers feel this system is too intrusive and does not allow them to actually conduct their work, for example, “If it’s a major fault, points, or its going to cause a delay, control have this nasty habit of wanting a ten minute update. We've explained this so many times and the answer that comes back is, 'Oh we need to be updated; we need to let the train companies know', Let me do my job, let me sort it and when I get a spare minute I'll phone you to let you know" (P6).

5.4.5 Theme 5: Not on-call

This theme discusses the period of time after the completion of a worker's shift whilst not on-call. This period of time should represent a detachment from work and indeed it should be a rest period. Whilst these themes are not directly related to on-call work these findings allow for a better understanding of the on-call scheduling system of work as they provide valuable background information that will help contextualise the work and life of on-call workers. Figure 5.5 shows a hierarchical visual representation of the lower-order themes associated with the high-order theme *Not on-call*.

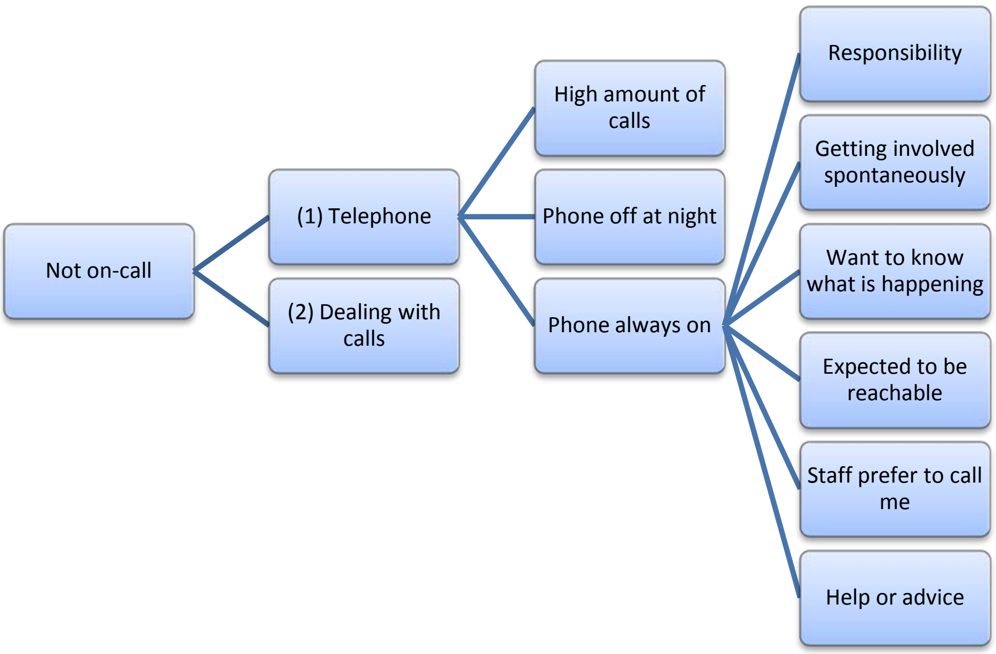


Figure 5.5 - Not on-call tree diagram

(1) Telephone

When not on-call workers are not required to be reachable outside working hours but, as will be discussed in section 5.4.6 Themes 6, 7 & 8: On-call arrangements, Management of on-call work, & Organisational culture there is a covert expectation that managers will be reachable at all times. What is more, managers are also expected to be informed of what is happening in their depot. Owing to this, there are 28 interviewees that choose to keep their telephones always turned-on, for example, "The way I work in my department and most of my colleagues the phones are always on" (P29), with at least nine of them stating they receive a large number of calls even when not on-call (e.g. "Probably, in reality I get as many or more calls when I'm not on call than when I am on call" (P33). Independently of this, a smaller number of interviewees (seven interviewees) choose to turn their telephones off during the night to ensure they can get a good night's sleep (e.g. "I don't leave my phone on at night now. If I go to bed and I'm not on call my phone gets switched off. So I can at least know I can get a decent night's sleep, because I can't function without sleep", P15).

There were several reasons interviewees presented to keep the telephone on and to be reachable out of working hours even when not on-call. The most common reason, put forward by 19 interviewees, is to provide help or advice to other team members or subordinates, for example, "I do not believe in letting somebody else struggle, worrying about something that I might have the simple answer for" (P20). In addition, 15 interviewees state their staff prefer to call them even when someone else is on-call (e.g. "I think people will phone whoever they know, someone who knows the area and the fault rather than somebody else. The guy in area x is not familiar with area y so they are going to phone me before they phone him", P24). Additionally, only 13 interviewees stated they choose to leave their telephones on as they are expected to be reachable at all times, and 12 interviewees more that they do it because they are responsible for their 'patch' and, as such, are expected to know what is happening so they choose to be watchful. To be able to get involved in faults spontaneously is a supplementary reason to keep their telephones on for at least 11 interviewees.

What is more, at least eight interviewees stated they constantly check their telephones (e.g. "You find yourself pager-watching, irrespective of whether you're on call or not", P15) and five stating they are incapable to resist checking their Blackberry telephone (e.g. "You shouldn't really, but I'm addicted to the blackberry, and you always look at the blackberry more and more and more", P49).

(2) Dealing with calls

When not working on-call, interviewees claim to be more selective when receiving calls and only picking-up the telephone for specific issues or from specific people, for example "After 10 o'clock at night I won't answer it unless it's someone I know or they send me a text first saying "it's urgent, I need to talk to you" (P4). Interviewees also declare that they are less careful with keeping their phone close-at-hand and at ensuring they always pick up the telephone (e.g. "If I'm not on call I don't take me phone with me wherever I go", P55).

5.4.6 Themes 6, 7 & 8: On-call arrangements, Management of on-call work, & Organisational culture

The following themes presented relate to logistics of arrangements and context. These offer context to the data identified in the previous themes and must therefore, be considered when interpreting these data.

The theme *On-call arrangements* discusses the general arrangements of on-call work, including the motivations of interviewees to work on-call, how their on-call periods are planned and arranged, and how the process of being called-out operates. The theme of management of on-call work discusses the different ways on-call work is prepared and supervised and the challenges associated with its management. Finally, the theme of organisational culture covers the different evaluations made by the interviewees regarding organisational communications concerning the company's vision and objectives. Figure 5.6, Figure 5.8, and Figure 5.9 show a hierarchical visual representation of the lower-order themes associated with the high-order themes.

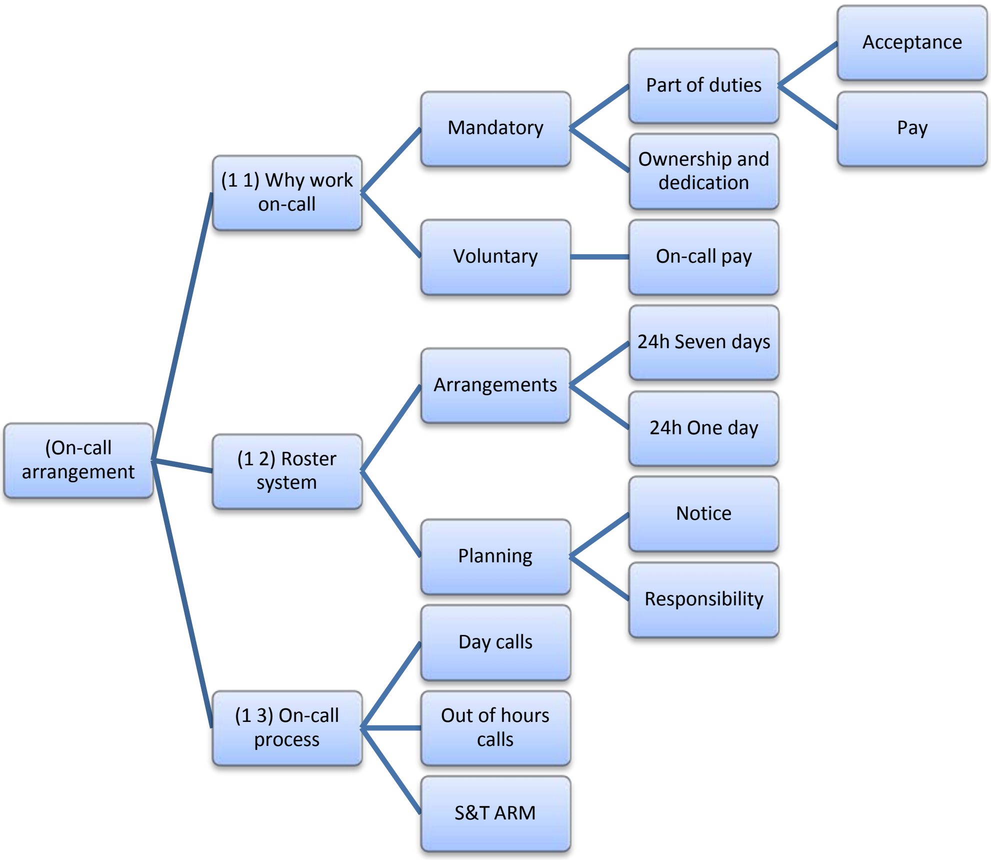


Figure 5.6 - On-call Arrangements tree diagram

(1 1) Why work on-call

Working on-call is not an option for managerial level on-call staff as it is seems to have been made part of the position they apply for, for example, "It's just part of the job I think. When you go for a job that's on call you know what you're landing yourself in for" (P48). For at least 17 managers it is their pride, dedication, and feelings of ownership towards their job that justify the long hours and the need to work on-call even without being paid for it (e.g. "You have got to have ownership of it. I'm not the sort of person who when the working day finishes just switch off. Because we are twenty-four seven cover I understand that people on till ten will have issues, people on the nightshift will have issues", P29).

For frontline staff the need to work or not to work on-call is not as clear. In some areas frontline staff are asked to volunteer to work on-call whilst in others on-call work is mandatory, for example, "The SM goes around and asks people if they want to do on-call" (P40). Independently of which system is in place at each area, frontline workers, in contrast with managerial level on-call workers, still receive both an allowance for being on stand-by and are paid overtime when called-out. When asked about the reasons to volunteer to work on-call, payment was the one main motivation stated by 13 of the 17 frontline members of staff interviewed, for example, “Money, that’s why you given up your seven days for.”

(1 2) Roster System

Four different on-call working arrangements were identified: two using on-call rosters and two without rosters. A roster is a plan of the turns of duty or leave for individuals or groups in an organisation, and is usually used to plan shiftwork. Similarly, an on-call work roster shows the turns of duty when a worker is required to work on-call or not. The roster-based arrangements are further divided into two methods: to be on-call for a period of 24h for seven consecutive days followed by a number of weeks ‘off-call’ or to be on-call for 24h during a full day and then be off-call for a number of days.

The majority of interviewees work under a *1 week in 4 weeks* (16 interviewees), *1 week in 6 weeks* (10 interviewees), and *1 week in 8 weeks* (eight interviewees) on-call rosters. In total, 13 distinct on-call rosters were identified. Slow rotating rosters, with a period longer than three weeks between shifts, represent the grand majority of worked rosters (57 interviewees). Due to this simple rotation on-call staff are usually given 13 weeks, six months, or one year advance notice of when they will be working on-call.

Non-rostered on-call was also divided into two arrangements; those who were always on-call (three interviewees) and those who are rostered on-call as business needs dictate (one interviewee). Non-rostered on-call was used to provide cover for regularly rostered on-call workers and for managers that choose to be contactable at all times.

(1 3) On-Call process

All infrastructure faults prompt a call to the depot responsible for that piece of track. All maintenance callouts originate at Fault Control. During office hours all calls are directed to the maintenance depot and are dealt with by the day staff meaning that on-call work effectively only happens outside office hours, for example, “Generally rule of thumb, it is, if there is an issue during the day, the local manager will deal with it, but obviously out of hours, you would be expected to deal with it” (P60).

Figure 5.7 shows an event driven chart of the process behind calls and its possible outcomes. There are three possible outcomes of a call. If the call takes place during working hours then the staff working the day or night shift will deal with the fault. If the fault occurs out of working hours then the on-call staff will be called in and they will either deal with the fault or if it they do not possess the resources, or if the fault does not warrant immediate attention, it will be added to the maintenance plan an dealt with next day.

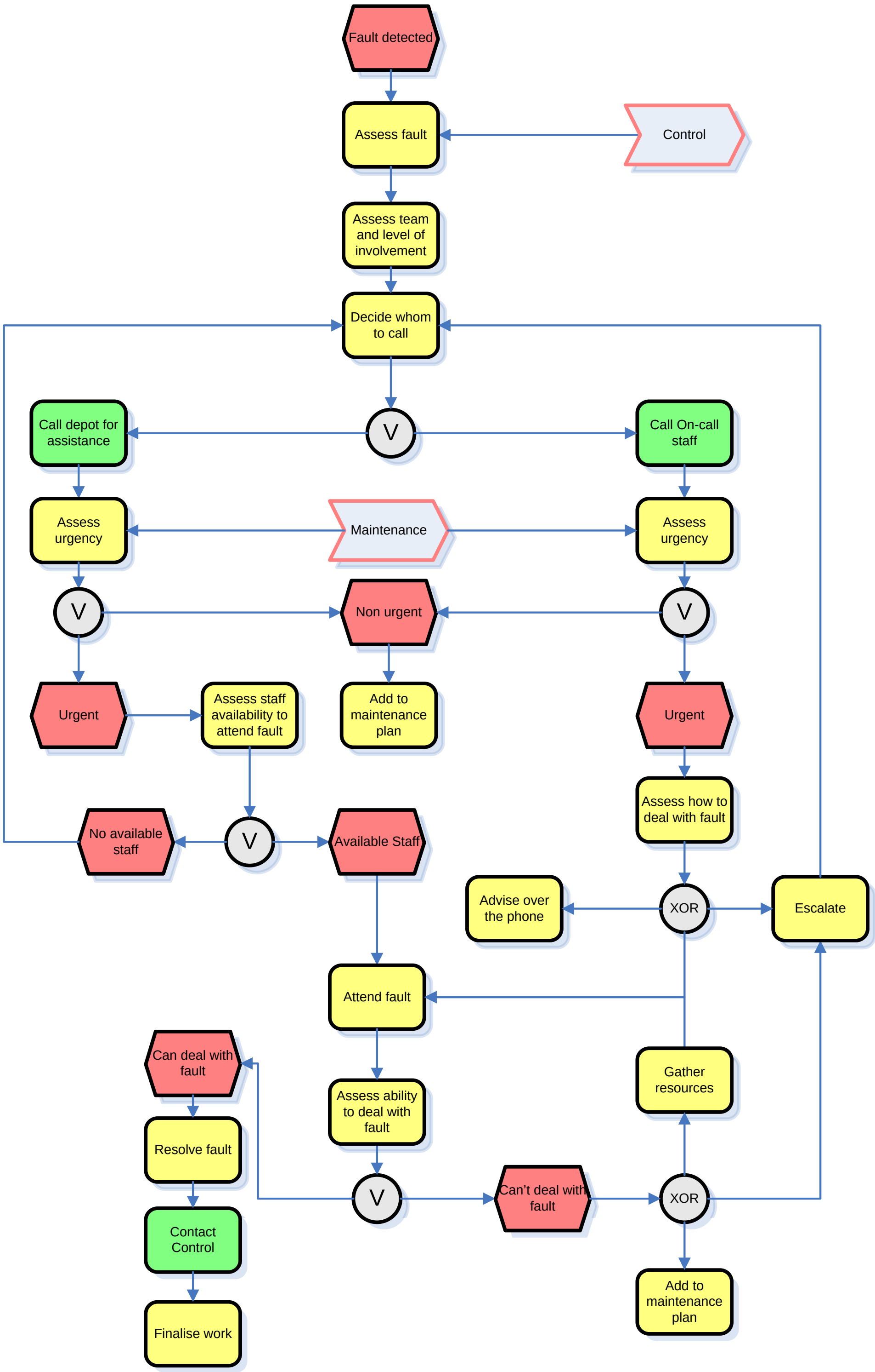


Figure 5.7 - On-call event driven chart

It is during the weekends that on-call work has the potential to be more disruptive as there will be no teams working the day shift. During the weekends whoever is working on-call will always be required to respond to each and every callout for those 48h, for example, "In effect we're the first port of call for every single bit of maintenance work. So come the weekends you can have, if you've got eight work sites and there’s problems on each you’d have eight different phone calls. That means eight different work sites you’ll have to visit" (P6).

There are usually four escalatory levels of on-call staff. Level 1 on-call duties are usually performed by frontline staff that effectively have a hands-on role and are responsible for the actual physical work involved in attending faults. Levels 2, 3, and 4 are usually advisory roles. In most cases, workers of higher on-call levels are not required to physically attend faults but might spend several hours on the telephone, giving advice to the lower levels, making decisions, and coordinating efforts with other teams. It is generally accepted that the first line of managerial support (i.e. level 2) will have the highest number of callouts as most issues do not require the involvement of the higher level on-call workers. Usually level 3 and 4 staff will only be contacted in case of higher impact incidents such as a derailment or where a fault threatens performance severely.

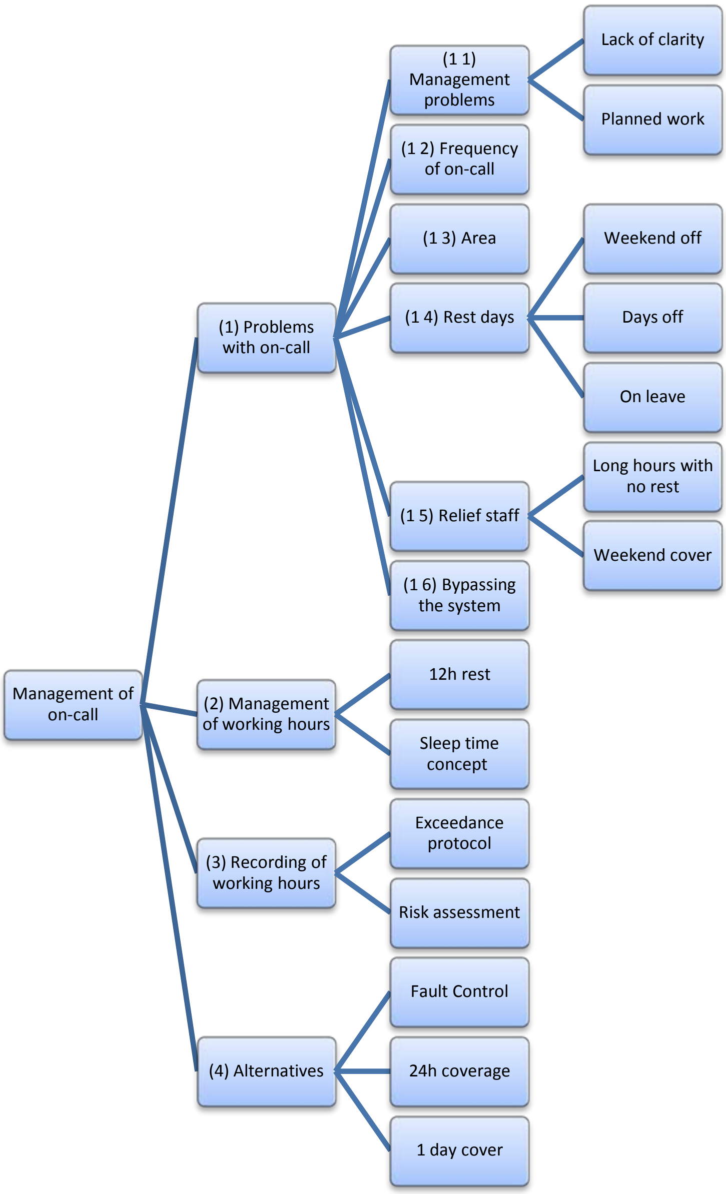


Figure 5.8 - Management of on-call tree diagram

(1) General problems with on-call

For most interviewees (65 interviewees) the on-call scheduling system of work is problematic and requires improving. Interviewees identified 34 problematic issues that range from the area covered when on-call to the way the on-call scheduling system is managed. Due to the large number of issues mentioned, only the most frequent are discussed.

(1 1) Management Problems

The most commonly mentioned issues with the on-call scheduling system of work were management issues. These were put forward by 39 managerial-level interviewees. These revolve around the topic of current on-call arrangements and their lack of clarity; the need to also maintain *normal working hours* when on-call in order to cover the work that must be managed during the day; and the problems associated with having short numbers of staff that, after a callout, need their rest and are unable to conduct the work planned for the day after.

The lack of specific guidance around the on-call scheduling system is a concern for a minimum of 21 interviewees. On-call arrangements in place in each DU do not seem to be specific or in fact to be clearly documented (e.g. "There is nothing written down, nothing at all", P23). Interviewees feel the arrangements have too many grey areas, with topics such as requirements and what qualifies as acceptable behaviours when on-call, needing to be made clearer. The most common areas that interviewees feel guidance is needed were:

- *Rest time* (e.g. "There is no guidance to tell us when you gave to be back at work after you got a call and when to come back at a reasonable time", P49).
- *Accommodation arrangements versus long drives* (e.g. "I don't know if it is a provision for staying in a hotel instead of driving home. I have never been informed if it is a provision for that", P21).
- *Response times,* so that workers know how much freedom they have to leave the house when on stand-by (e.g. "There is no documentation about what you are allowed to do when on-call or not - distance or amount of time to respond", P40).
- *Communication requirements* (e.g. "The thing is you don't want to go home and then come back the next day and have a strip torn of you because you haven't given someone the information in the morning even though you may have been in twenty hours", P27).
- *Reasons to be called-out*, where staff would prefer to have a list of specific issues that require a specific level of on-call to be contacted (e.g. "I guess it's more guidance for the controllers as to what you should get involved in. And more agreement with our bosses as to what they think we should be involved in. Because there's an expectation that if something's causes delay then the engineer needs to be involved, the IMDM or the IME needs to be involved and actually, if there's nothing I can do to add value to the situation, what's

the point? I'm not at work. If it's just to keep me up with what is happening and sometimes the controllers call just so that you know if you get asked any questions in the morning, this has gone on. Send me an email. I don't need you to call me and tell me that at 2am in the morning", P30).

(1 2) On-call frequency

As discussed before most interviewees work week long on-call periods followed by a number of weeks not on-call. Fast rotation rosters (1 week in 2 weeks, 1 week in 3 weeks, and 2 weeks in n weeks) are not considered workable by at least 31 interviewees as they do not allow for enough rest or for a good work-life balance. The most common strategy to deal with this problem is to expand the on-call area of coverage by merging on-call rosters of two or even three depots. For example, "If we didn't do it with Depot x, we'd be on call 1 in 3. Which is not sustainable, it would burn you out. So we do it 1 in 6 at our level" (P15). Although this strategy does resolve the problem of high on-call frequency it also brings about other issues for at least 27 interviewees which are discussed below.

(1 3) Area

Having two or even three depots merge their on-call roster, and in effect reducing the frequency of on-call work, also means staff has a greater geographical area to cover. This is a common strategy used by on-call staff of managerial level and was in place in all five DUs where interviews were conducted. This strategy is not an option for frontline staff as their type of work requires a greater knowledge of local infrastructure and, as such, is not as easily transferable.

Increasing the geographic area covered when on-call raises two issues for on-call staff; the travel distance and amount of time needed to respond to a callout, and the number of callouts. With an increase in the geographic area covered, when required to attend a fault, on-call managerial level staff may be required to travel long distances to reach the fault as each depot can cover very large areas, for example "When on-call I cover 700 track miles" (P14). Even when not required to attend the fault, the potential number of callouts is multiplied as there will be many more teams per on-call manager e.g. "By doing 1 in 6 and covering a bigger area the amount of failures we get on our area is horrendous. It's horrendous. And they're always ringing the on-call man" (P4).

(1 4) Rest days

Being on-call when on annual leave, in theory should not happen, as most on-call workers know their on-call arrangement well in advance as can plan around it. However, due to staff reduction, sickness, and other unforeseeable events on-call rosters can change. For a minimum of 22 interviewees being on-call when on leave was identified as an issue. Due to the weekly on-call periods arrangements, when one member of staff is removed from the on-call roster, the whole system changes considerably and workers can find themselves being on annual leave and still being rostered to work on-call. For example “I might be off for a week or so but still be on-call waiting for a phone call - when you are off you shouldn't be on-call. You are really never away from work because it is on your mind. You can swap but you shouldn't have to do that” (P45).

(1 5) Relief staff

On-call arrangements where only one member of staff is available per level to deal with faults do not afford much resilience to the system and leave on-call workers unaided in the event of being unable to carry on dealing with the fault. At least 19 interviewees feel that the non-existence of a relief system in place when on-call is problematic (e.g. “There is no system for someone to stand in for us”, P22) and escalating the work to the next on-call level is not always an option as some jobs require very specific skills (e.g. “You couldn’t call someone else out instead, cause there is just not the people with the skill s anymore”, P11). Due to this shortage of on-call staff, to be able to close a fault, workers many times feel forced to breach the working time limits as they feel there is no one to relieve them when they reach the 12h limit[15], for example, “You couldn’t realistically walk away and say, ‘Right, I have done my twelve hours. That’s it now’; there would be no one else to replace you but that’s how the system seems to be flawed” (P21).

(1 6) Micro management and by-passing the on-call scheduling system

When on-call, interviewees feel senior managers often choose to get involved in faults before they are called-out with at least 18 managerial level interviewees stating they sometimes do get involved before being called-out. For example, “With on call, you tend to proactively get involved in things. So you’re there to proactively drive

[15] Network Rail’s working time limits are discussed in detail in chapter 2.

and manage through what’s going on. So if you see signal failure, this that and another, I normally will make a phone call to the level 1 on call, saying ‘any issues, got enough men, what’s happening, so and so, ok good thanks, carry on no problem’” (P15).

A number of interviewees (seven interviewees) feel this behaviour instead of helping resolve the fault can cause more disruption than when managers choose not to get involved and instead wait until being called-out (e.g. “I’ve got a lot of repeat phone calls from the IMDM and then somebody else will ring you two minutes later asking you all the same questions again. And then you start emailing the updates, you include the route control manager, and then the guy on the control desk comes and phones and asks you the same stuff again because he isn’t speaking, obviously, to him”, P3). Some of the possible reasons for this behaviour are due to the current organisational culture of the company; workers are expected to be all knowledgeable of issues in their areas and to be able to provide answers to senior managers. This is discussed in more details below.

(2) Management of working hours

In accordance with both the European Directive, the Hidden rules, NR own fatigue management standard (NR/ERG/003), workers are entitled to a minimum of 12h rest between periods of work[16]. Most interviewees were aware of this and at least 26 stated they operate under this regulation, for example, “Between you finishing one shift and coming in to work and starting again it should be a minimum of twelve hours, I believe is the criteria” (P27). Nonetheless, at least 18 interviewees stated they still operate outside this regulation and still use what was known as the *sleep time concept* where workers are allowed an agreed amount of time to rest that is shorter than 12h. This originates from legacy terms and conditions from the time when all rail maintenance was conducted by a number of contractor companies such as Ames or Carillion. Eight or nine hours, instead of 12h, are the usual amount of hours of rest associated with the *sleep time concept* but there were several versions of this concept in place at the time of the interviews. This concept seems to have originated in old maintenance contractors terms and conditions and somehow survived NRs amalgamation of maintenance, for example, “They’re still on old

[16] For details see Chapter 2, section 2.5 Regulations for more detail.

contract terms and conditions so if they're on call before eleven and they completed their turn before eleven, eleven pm, then they'd be expected to come in for their normal turn at 7h15min" (P69).

(3) Recording of on-call working hours

As with most on-call arrangements there are no clear guidelines in place to help workers manage their on-call work and, as such, on-call working hours recording hours' arrangements are also managed locally. Some frontline interviewees (seven interviewees) start logging from the moment they receive the callout whilst others do it from the moment they exit the house. The differences found could be due to local arrangements but this is not the case as interviewees from the same area indicated different arrangements. It seems that even within the same area, arrangements vary, potentially due to legacy arrangements also.

(3 1) Risk Assessment

The NR fatigue standard NR/ERG/003 states that workers are not allowed to work for periods longer than 12h, and also presents a list of situations where upon the conduction of a satisfactory risk assessment workers are allowed to exceed this limit and to continue working. Of all interviewees only 20 stated they follow the procedure and fill in the form. At least five interviewees admitted not going through the process and instead filling the exceedance form the following day instead of when the exceedance actually takes place, for example, "There's no risk assessment then because it's done in arrears. So the form is a declaration form, in arrears" (P15).

(4) Alternatives

A set of possible alternatives to improve the way on-call work is managed at NR was put forward by 31 interviewees with the most common option presented (19 interviews) being to work the night shift when on-call which 15 interviewees already choose to do[17]. To completely remove the on-call scheduling system and arrange for 24/7 coverage instead was a suggestion of 11 interviewees (e.g. "I think in this day and age, personally I believe with this industry, I just think there should be a 24/7 cover here, to deal with problems. We are a 24/7 industry, so to rely on people out of hours to come in, I just think in this day and age I think it's quite poor", P35).

[17] Section 5.4.2 Theme 2: Stand-by discusses this option and associated issues in detail.

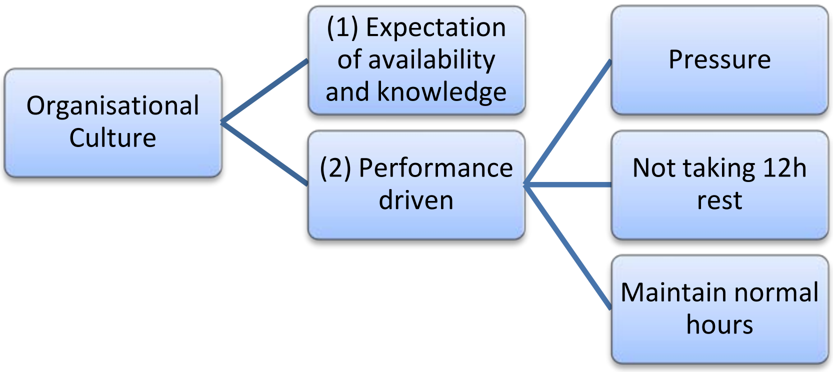


Figure 5.9 - Culture tree diagram

(1) Expectation of availability and knowledge

There were a minimum 22 managerial level interviewees who felt that there is expectation for managers to be available to answer the phone and deal with issues at all hours independently of being on-call or not. For example, “It’s just an assumption that you’ve got to do it. I mean I am not on-call this week, but I’ll have the IMDM yesterday phone me up at 8 o’clock at night, you know, while I am not on-call. You know, you are expected to be on contact all the time” (P67). As discussed in more detail in section 5.4.5 Theme 5: Not on-call, whilst this expectation is not explicitly communicated to members of staff, it is made clear to managers that they are responsible for managing their own areas and that they are the ones who will be asked to explain themselves in case of a perceived failure. This is the case for at least 22 interviewees that claim they are expected to know what is happening in their areas 24/7 independently of being at work or not. For example, “When somebody rings you and says ‘what’s happening with this’ and you don’t know about it. It’s that fear of being caught out. There’s an expectation that you’ll know about things even if you’re not on call” (P15).

(2) Performance Driven

A minimum of 12 interviewees felt the company’s organisational objectives have changed in recent times. There is a perception NR went from a company aiming to be ‘world class’ to a performance oriented company where the key objectives are to reduce costs and to improve performance by minimising delay minutes. For example, “We had a failure yesterday, and because it racked up a few hundred minutes, people are phoning me. You know, it wasn't so long ago, it was bound to be world class and all that kind of, and that has all died to death. And it is all about performance, getting everything right" (P67).

This in turn seems to cause staff across the company to feel more pressured now to achieve objectives, resolve faults, and in fact to be more efficient and effective, for example, "Speaking to other guys within, it's across the board now, I'd say really, more pressure, it's a company thing" (P66). Moreover, for at least 12 of the staff interviewed this pressure is now part of their day to day job, for example, "Lot of pressure put on people to sort it out, where are your blokes? What are they doing? All these sort of questions that people throw at you" (P33).

5.5 Discussion

The interview process was carefully developed to allow the exploration of both on-call planning and management, and the impacts it has on on-call workers. The semi-structured protocol allowed the researcher to explore the themes that were more important to each participant and, as such, whilst not all interviews covered the same topics, all data collected represents the more relevant issues for each interviewee.

The inductive thematic analysis protocol was used successfully and was highly productive with results providing a great insight into the on-call arrangements in place at Network Rail Infrastructure Maintenance and in the exploration of on-call impacts. This protocol revealed itself ideal to interpret the data collected by identifying major factors and the connections between factors; many of them hierarchical or temporal. Nonetheless, there were difficulties in grouping the themes as the issues and practice of on-call work are so closely intertwined. For example, fatigue is not just about the callouts themselves but also about the experience of being on-call and the need to attend on site. This difficulty in understanding all the interrelationships between the different factors is also why the development of the framework is so vital for on-call research because it tries to make explicit all these interrelationships.

The results support the differences identified from the literature between on-call and other types of working hours schedules, like shiftwork. It is the idiosyncratic unpredictability associated with on-call work that differentiates it from other types of work schedules. In all other types of scheduling systems workers possess the knowledge of when they are expected to work and for how long. This allows them to prepare for their shift and conduct any family and social activities around that schedule. With on-call work this is not the case and the inability to organise their time causes workers to feel anxious and prevents them from disconnecting from work. Furthermore, this anxiety then affects workers' quality of sleep and as a result causes their fatigue levels to rise. At least one other study has found similar results where on-call ships' engineers sleep quality deteriorated due to the prospect of being awakened, (Torsvall & Åkerstedt, 1988). These are some of the reasons why a large number of on-call workers dislike the on-call system of work.

The unpredictability of when a callout might be received can also become paralysing and prevent many workers from maintaining their *normal* lives with many interviewees stating they prefer not to have social arrangements for the week they are on-call. On-call work is also a cause of conflict at home. Many on-call workers partners are unhappy with the time on-call arrangements take from family life as on-call workers might be disturbed and required to spend long period of time on the phone or to attend the fault when on-call. Moreover, when callouts occur during the evening both the on-call worker and his/her partner are disturbed. Other research identified similar results, where the impact of callouts were also felt by the family members (Imbernon et al., 1993). It was thought that the on-call level could be a moderator factor and that those on higher levels, who in theory have less calls, would "try to maintain a normal life" whilst those on lower levels would be less likely to. This was not the case, nor was it regarding number of years working on-call. In fact no pattern was identified and the results seem to be distributed evenly. It might be that personality traits are the differentiating factors in play here but personality factors were not part of the scope of this thesis and therefore were not researched.

What is more, the sleep disruption caused by callouts during the night and its subsequent impact on fatigue and performance are major concerns regarding the on-call work. Although only a small number of interviewees perceive their abilities to be severely impaired, research has identified a clear relationship between sleep loss, fatigue, and performance (e.g. Van Dongen et. al, (2003); Kaida et. al, 2007). The inability to fall back asleep after receiving callouts was also pointed out by many interviewees. This is mainly due to the inability to relax and instead to revisit in their minds their decisions. Unfortunately, at this stage, without the knowledge of the specific number of calls received it is impossible to draw any conclusions regarding how disruptive a certain number of calls or the timing when they occur can be. Understanding these effects was one motivations behind work presented in the next chapters.

The reasons to be called-out when on-call are many and varied but there is also a disproportionate amount of what the interviewees refer to as *silly* calls. These are calls that could have waited until the morning, or calls that did not require the involvement of the on-call worker. Many of these calls seem to originate from Fault Control so other factors must also be at play but, based on the information collected it is not possible for the researcher to speculate on these. It is clear, however, that on-call workers feel there has been an erosion of the skills of controllers that in turn leads to more calls being directed at them. There is the need to a better understanding of what calls on-call workers need to be involved and what which stage. There is also the potential for many of these calls to be shifted to other roles in the company. Not surprisingly, many interviewees feel more fatigued when working on-call, not only on the day after an on-call shift but due to the accumulated effect of sleep deprivation. It is, however, not farfetched to think that in an industry with a long and well-rooted male, and potentially even macho, culture many workers will shy from admitting feeling tired or stressed. In such a culture, even a flexible swapping and covering system as is the one available at NR will not be effective if workers do not make use of it when feeling tired, as indeed only one third of interviewees admitted taking extra rest and starting late or finishing early the next day. One, even less common, strategy to deal with on-call work explored by a small number of participants was to work the night shift when on-call. This, in theory, would prevent the disruption to sleep, and the family and social lives of on-call workers. Unfortunately, this in itself is not a solution, as on-call shifts are longer that the usual night shift, the on-call worker is still needed to cover that period of time. Even more so, only a very small number of interviewees admitted using some sort coping mechanisms, (going to bed earlier and taking naps), to deal with the resulting fatigue of working on-call. It can be expected that these ways of dealing with fatigue are more common amongst on-call workers. It might be that these were either not identified as specific behaviours by the interviewees or not identified by them as specific to on-call. The relationship between anxiety, quality of sleep, and fatigue is a temporal one, as anxiety causes an inability to relax and disturbs sleep which in turn leads to fatigue (e.g. Torsvall & Akerstedt, 1988; Van Gelder & Kao, 2006). On the other hand, the constant state of arousal created by feeling anxious can also be more draining on the body and increase fatigue (e.g. Costa, 2003).

Frontline on-call workers are required to attend site for almost every callout but managerial level on-call workers are not usually required to attend site. Fatigue build-up is an issue when attending site for both for frontline and managerial staff. This is associated with the long distances they frequently travel to site. Much the same, as with simply providing advice over the telephone, the lack of enough recovery time afterwards, further exacerbate this effect as other research has shown (Åkerstedt et al., 2000; Belenky et al., 2003).

On-call arrangements, where week-long rosters seem to be the preferred method of organising on-call work, create high risk situations. Being required to make critical, speedy decisions in a situation of reduced sleep quality due to anxiety, and potentially after several nights of disrupted sleep, means putting at risk both the people implementing the decision and hundreds of train passengers using the track. Day-long rosters can, in theory, be more beneficial to workers and reduce the risk to on-call managers' fatigue and health. By only working on-call for one day, continuous anxiety is removed from the workers' mind and when called-out the workers will be able to recover faster from the disruption as it will be limited to one night. This is an option that could quickly reduce the levels of stress and fatigue in on-call workers.

Frontline workers, whom are not required to work on-call, choose to do so mainly for the on-call allowance and overtime pay which is not available for mangers. With 12 hours rest breaks in place for most, and the sleep time concept for the remainder, frontline workers fatigue risk is reduced. For on-call managerial level staff this is not always the case. Due to both the organisational culture pressure to always possess all the knowledge regarding their depot and the need to keep their daily appointments, managers often choose not to, or are unable to, take a period of rest after being called-out. Furthermore, due to the expectation put on them, managers frequently choose not to turn off their phones when not on-call so that they can both get involved in faults and be available to provide help to on-call co-workers. The implications of this to managers' work-life balance and fatigue management are tremendous and demonstrate the unrealistic approach to on-call work in place at NR. To expect managers to be available and in charge of their depots 24h a day reveal that on-call arrangements were clearly not updated as the company grew and the current on-call management system is not adequate to the company's needs.

With the current arrangements and the pressure put on on-call managerial level staff to be almost omniscient with regards to their depot, it is not surprising that most would prefer not to have to work on-call. As recommended by some interviewees, to truly manage a 21st century railway 24h coverage is required. This does not necessarily require on-call work to be scrapped but it does require it to be extensively modified so that staff working shifts are not then required to be available out of working hours to deal with faults. There is the possibility of creating specific on-call teams whose only purpose is to cover on-call work for periods of time when the normal volume of work does not warrant full shift coverage, i.e. evenings and weekends.

As far as it could be ascertained, up to this point, both in industry and academia, on-call work has been treated as one unitary event (e.g. Imbernon et al., 1993; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988). This study demonstrated that there are in effect three separate on-call work events - stand-by, receiving callouts, and responding to callouts, with at least two events being general to all industries – stand-by and receiving and responding to callouts. Each of them impacts differently on stress, sleep quality and quantity, fatigue, and the well-being of both workers and their families. Being on stand-by in particular was not predicted by the literature reviewed nor were the effects mentioned by the interviewees (e.g. anxiety, reduced sleep quality). The actual callouts (receiving and responding to callouts) can cause disturbed sleep due to wake-ups and, therefore, lead to the physiological impact of reduced sleep but the anxiety of being on stand-by both further reduces sleep (increasing fatigue), and is a major source of 'unhappiness' for on-call work.

5.6 Framework iteration

The work conducted for this study identified a large number of factors that on-call workers associate with on-call work which were not initially considered. All these contributed to the iteration of the initial framework compiled from the available literature at the end of Chapter 3. The main changes to the framework originated from the three on-call scenarios identified, the on-call arrangements considered important by the interviewees, and the relationships identified between the factors. For one, the initial framework did not consider the existence of three separate on-call scenarios. The unwanted outcomes that arise from each of these scenarios or the ways in which they occur was also not considered or accounted for in the initial framework. The data collected from this study has allowed the framework to be iterated to better represent the different facets and influences of on-call work.

The framework now identifies the situation of solely being on stand-by as a specific on-call event which is influenced separately by the on-call roster and its limitations regarding the workers' leave and rostered days off. The framework also illustrates how being on stand-by alone leads to higher anxiety, which in turn leads to sleep disruption, reduced well-being, and can affect the family and social lives of on-call workers. Receiving callouts and attending callouts may also occur when on-call but (clearly) only after being on stand-by. Due to teamwork and the possibility to swap or cover an on-call shift the impact of these scenarios will be influenced by these events. When they do occur their consequences are also dependent on the number, timing, and duration of callouts. For example, it can be expected that a higher volume of callouts will cause a greater disruption to sleep than a lower number. Many moderating factors which can influence the impacts of all three on-call scenarios were also identified – personality, age, experience, the weather, and on-going work. The updated framework is represented below in Figure 5.10.

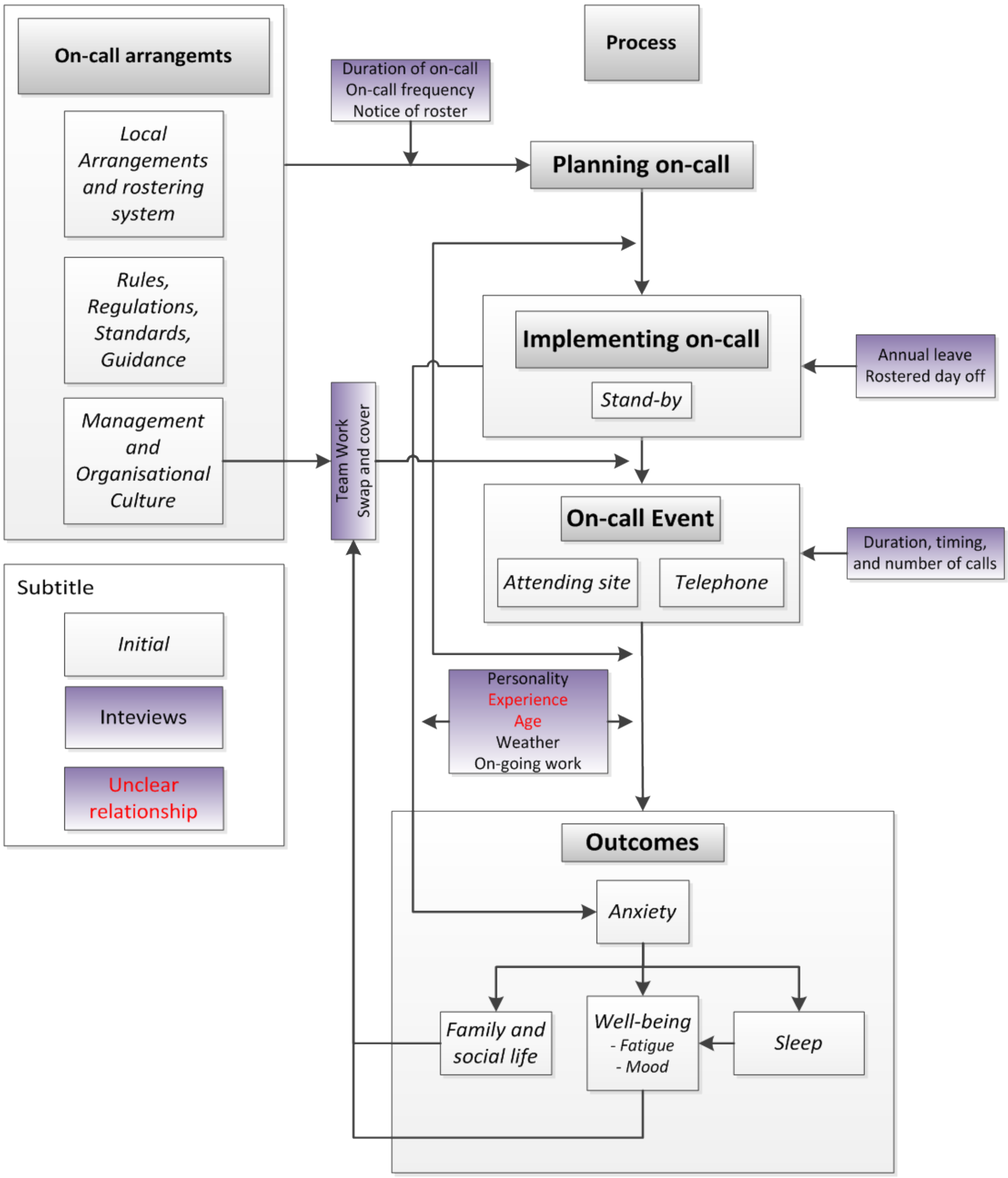


Figure 5.10 - Iterated on-call framework

The general influencing factors identified in the initial framework (e.g. rules, regulations, standards, guidance) are maintained in this iteration as all these factors are still present and represent semi-stable on-call arrangements – local arrangements, rostering systems, rules and regulation, and organisational culture. Contrary to what was initially believed, these influence the planning of on-call work but not what actually occurs after the planning – the actual on-call work. Moreover, this study also identified a number of moderating factors between the on-call arrangements and the planning of on-call. These are the duration of the on-call duration (one day versus one week), the on-call frequency (*n* weeks in *m* weeks), and the notice period for on-call work. All these have an influence on all on-call scenarios and their impacts. For example, working for a whole week on-call can be expected to be more damaging that just working for one day.

5.7 Methodological implications

The results found from the interviews identified a number of on-call specific factors that were used both to iterate the initial on-call framework developed and to focus the scope and aims of Study 2. Namely: fatigue, anxiety, performance, family and social lives, sleep quality, and sleep quantity. It was also identified that managerial level on-call staff are more at risk of suffering from all the factors identified whilst frontline seem more protected. It was, therefore, decided that study 2 would focus solely on managerial level on-call workers. Study 2 aimed to explore how the factors identified are experienced in the three on-call scenarios identified and which components of performance workers perceive to be affected, e.g. decision making, attention, quality of work. Due to the interpretative nature of analysis qualitative data and the limited number of DUs where the interviews were conducted study 2 aimed also to confirm the relevance of the factors identified, to explore the generality of the findings, and to explore the geographical distribution of on-call arrangements and management procedures.

5.8 Chapter conclusion

This chapter described the preparation, execution, analysis, and results from semi-structured exploratory interviews conducted with NR on-call Infrastructure Maintenance staff. This was the first study conducted for this thesis and aimed at exploring several of the objectives of this thesis described in section 1.2 Aims and Objectives of Chapter 1 and the research questions associated with each one and described in Table 3.1 of Chapter 3. The study was successful with the research questions being partly answered and with the initial framework developed from the literature being iterated.

The next chapter discussed the second on-call specific research study conducted for the thesis. It details the preparation, execution, analysis, and results from a closed questionnaire conducted with NR on-call maintenance managerial level staff.

Chapter 6 – On-call specific questionnaire

6.1 Chapter summary

This chapter discusses the second on-call specific research study performed for the thesis. It details the preparation, execution, analysis and results from a digital survey questionnaire performed with Network Rail on-call maintenance managers. The findings are discussed in light of the expectations and predicted results and the chapter concludes with the implications of the findings both for the initial framework developed and for future work.

6.2 Background

From the work performed previously on safety behaviours of maintenance staff, through the conduction of fatigue management audits and through the review of Network Rail's working hours, standard on-call work was identified as the research topic for this thesis. During this work it became apparent that on-call managers were expected to be almost omniscient regarding the work being performed in their depot at all times. These pressures were coupled together with an apparent unawareness by senior managers of any processes and procedures implemented across GB to manage on-call work.

An exploration of the available on-call literature showed that on-call as a research topic has received very little attention and is lacking in descriptive information. Two different types of on-call work are, nonetheless, found in the literature; the *proximal* on-call scheduling system where workers remain at their workplace when on-call (e.g. doctors) and the *distal* on-call scheduling system where workers are away from their workplace (e.g. rail workers). In spite of the lack of attention this system has received a European wide research has shown that on-call work is quickly becoming the most common system of work across Europe (Eurofound, 2012). This is probably due to it being a cheaper alternative to other types of work such as shiftwork. It is the *proximal* on-call scheduling system that has received more attention in both industry and academia. A number of associations have been found between on-call work and sleep, cognitive performance, and well-being indicators, such as mood, stress, and mental health.

A negative association between on-call work and sleep quantity (Van Gelder & Kao,

2006) has been found, most likely due to anxiety about being awoken up by an alarm, or a callout (Torsvall & Akerstedt, 1988). Cognitive performance, mood, and well-being have also been found to have a negative association with on-call work (Eurofound, 2012; Heponiemi et al., 2008; Imbernon et al., 1993), and so have health related consequences, namely, stress, mental health, and personal safety (Nicol & Botterill, 2004). Sleep disruption and sleep inertia research have also identified that sleep disruption has an effect on performance (Bonnet & Arand, 2003) and well-being (e.g. Goyal, Gay, & Lee, 2009). Sleep disruption and sleep inertia are two clear characteristics of on-call work. In addition, sleep disruption has been identified as a leading cause of fatigue (Åkerstedt, 2000).

At Network Rail, on-call is arranged through the *distal* on-call scheduling system and on-call work is described as the situation where a worker is waiting to respond to an emergency callout or answering a query from people working in the field (ORR, 2006). This is a system that was initially designed to ensure that in the event of emergencies, during the periods between shifts, there would be a number of qualified workers available to provide expert advice or resolve any faults that might occur in the infrastructure. The interviews performed in Study 1 allowed for the exploration of both on-call arrangements and the impacts of on-call work on staff where the major factors and the connections between factors; many of them hierarchical or temporal were identified.

The analysis of the interviews showed that week-long rosters seem to be the preferred method of organising on-call work at Network Rail. These arrangements are managed locally and a great deal of freedom and flexibility is given to both frontline and managerial staff to swap, change, and cover rosters. These are coping arrangements that are frequently used by staff to help achieve a work-life balance. It is the inherit unpredictability of on-call work which is the main differentiating characteristic of on-call work and other types of work schedules. Not knowing if and when a callout will occur leads on-call workers to the impossibility of organising their time, causing workers to feel anxious. Furthermore, this anxiety then affects workers' quality of sleep and as a result causes their fatigue levels to rise. The unpredictability of when a callout might be received can also become paralysing and prevent many workers from maintaining their normal lives, as they might be disturbed and required to spend long periods of time on the phone or to attend the fault. What is more, the sleep disruption caused by callouts during the night and its subsequent impact on fatigue and performance are major concerns regarding the on-call work. Although only a small number of interviewees perceive their abilities to be severely impaired, research has identified a clear relationship between sleep loss, fatigue, and performance (e.g. Van Dongen et. al, (2003); Kaida et. al, 2007).

From the interviews it was also apparent that frontline workers are less at risk than managerial staff as the 12 hours rest policy is enforced for most, and the sleep time concept for the remainder. Although fatigue management research shows that these are not ideal arrangements, frontline workers' fatigue risk is reduced when compared to that of managers (e.g. Knauth, 1996; Knauth & Hornberger, 2003; Rosekind et al., 1995; Spencer, Robertson, & Folkard, 2006). On-call managerial level staff, due to both the organisational culture pressure to always possess all the knowledge regarding their depot and the need to keep their daily appointments, frequently choose not to, or are unable to, take a period of rest after being called-out. Furthermore, due to the expectation put on them, managers often choose to keep their phones on when not on-call so that they can both get involved in faults and to be available to provide help to on-call co-workers. For these reasons it was decided that the second study in this thesis would focus only on on-call managerial staff. The aim of Study 2 was to assess the generality of the main findings of Study 1 by exploring objectives three to six of this thesis described in section 1.2 Aims and Objectives of Chapter 1 and to attempt to answer the research questions related with each objective, as described in Table 3.1 (chapter 3) and replicated below.

	Research questions
Objective 3	• What is the relationship between callouts and the perceived consequences of on-call work? • What is the relationship between on-call work arrangements and management procedures?
Objective 4	• What are the on-call specific characteristics that lead to consequences? • How do these factors interact and what are their consequences?
Objective 5	• How can on-call work be monitored? • What are the most damaging factors associated with on-call and how can they be modified to reduce negative consequences?

6.2.1 Infrastructure maintenance geographical arrangements

To be able to interpret the results of the study presented in this chapter a more detailed knowledge of the organisation of the rail industry is required. The next section provides a short introduction to the geographical arrangements of Network Rail's Infrastructure Maintenance department.

6.2.1.1 Routes

Routes are the main geographical organisation of Network Rail's operation. Routes are defined by a general rail path or track that connects a set of strategic locations. Network Rail's geographical organisation is arranged under eleven different routes. Each route director is responsible for defining the scope of work needed to maintain the infrastructure. As such, each route's management objectives and procedures regarding on-call work have the potential to, and do, differ.

6.2.1.2 Delivery Unit

Delivery Units (DU) are the local structures of each route responsible for managing a given section of the infrastructure network. In practice, this signifies the maintenance and management off all assets, for example, track equipment, such as, points, signalling, and electrification equipment.

6.2.1.3 Section

Sections are the subdivisions of DUs and are organised in depots. Each section is responsible for managing a small part of the infrastructure network covered by the DU. The number of sections per DU can vary from a couple to ten plus. Table 6.1 below details the DUs per route.

Table 6.1 - Infrastructure Maintenance geographical arrangements

Route	Delivery Unit	Route	Delivery Unit
London North East (LNE)	Hitchin	**Kent**	Ashford
	Lincoln		London Bridge
	Doncaster		Orpington
	Sheffield	**Sussex**	Brighton
	Leeds		Croydon
	Newcastle	**Wessex**	Clapham
	York		Eastleigh
London North West North (LNWN)	Chester		Woking
	Crewe	**Scotland**	Edinburgh
	Manchester		Perth
	Carlisle		Glasgow
	Preston		Motherwell
London North West South (LNWS)	Bletchley	**Western**	Reading
	Stafford		Swindon
	London Euston		Bristol
	Saltley		Plymouth
	Sandwell-Dudley	**Wales**	Cardiff
Anglia	Colchester		Shrewsbury
	Romford	**East Midlands (EM)**	Bedford
	Tottenham		Derby

6.3 Hypotheses

The survey, being constructed partly to explore the generality of the results found in Study 1, allowed the researcher to compile a list of hypotheses. On-call work for the interviewees in Study 1 was organised in rosters, was mandatory, and was not aligned with shiftwork, thus making it possible to be rostered on-call when on a rostered day off. For this study it is therefore, hypothesised that:

On-call arrangements

hypothesis 1. on-call rosters will be organised in rosters

hypothesis 2. on-call work will be mandatory

hypothesis 3. it will be possible to be rostered to work on-call whilst on annual leave hypothesis 4. it will be possible to be rostered to work on-call whilst on a rostered day off or on a rostered weekend off

hypothesis 5. increased pay will not be a reason to work on-call

Interviewees in Study 1 also identified two main reasons for feeling anxious when working on-call. These are uncertainty about when and if a callout will occur and the anticipation of a callout (see section 5.4.2 Theme 2: Stand-by, (1) Anxiety for more details). As such it is also predicted that:

hypothesis 6. uncertainty about when a callout will occur will be a cause of anxiety

hypothesis 7. anticipating a callout will be a cause of anxiety

Similarly, well-being is expected to be more affected when on-call than when not on-call, and satisfaction with on-call work is also expected to be more affected than satisfaction with the job in general. Both Study 1 and the available literature support these hypotheses. Interviewees stated that well-being is severely affected by on-call work (see section 5.4.2 Theme 2: Stand-by and in particular sub-section (1 2) Consequences section 5.4.3 Theme 3: Receiving callouts for details), and other studies have found that, for example, practitioners working more than 40 hours on-call per week have lower job satisfaction and higher turnover intentions (e.g. Heponiemi et al., 2008; Imbernon et al., 1993; Nicol & Botterill, 2004).

hypothesis 8. fatigue as a well-being indicator will be significantly different when working on-call and not working on-call work

hypothesis 9. Stress as a well-being indicator will be significantly different when working on-call and not working on-call work

hypothesis 10. general well-being as a well-being indicator will be significantly different when working on-call and not working on-call work

hypothesis 11. satisfaction with time for family life as a well-being indicator will be significantly different when working on-call and not working on-call work

hypothesis 12. satisfaction with time for social life as a well-being indicator will be significantly different when working on-call and not working on-call work hypothesis 13. satisfaction with on-call work will be significantly different from satisfaction with the job in general

In the same way, interviewees in Study 1 believed that roster frequency (the period of time between on-call weeks) is one of the factors that affects both well-being and satisfaction with on-call work. Fast rotation rosters (1 week in 2 weeks, 1 week in 3 weeks, and 2 weeks in n weeks) are believed to not allow for enough rest or for a good work-life balance 5.4.6 Themes 6, 7 & 8: On-call arrangements, Management of on-call work, & Organisational culture, (1 2) On-call frequency). As such, it is hypothesised that:

Implementing factors

hypothesis 14. well-being (as a composite score of fatigue, stress, general well-being, satisfaction with amount of free time for social and family life) when working on-call will be significantly different between slow and fast rotating rosters (as defined by participants in Study 1)

hypothesis 15. satisfaction with on-call work will be significantly different between slow and fast rotating rosters (as defined by participants in Study 1)

Shiftwork literature has found some support for the role of experience and the ability to deal with the negative consequences of shiftwork (Duclos et al., 2012; Gillberg et al., 2003). This was also mentioned by interviewees in Study 1 who feel they become more able to deal with the negatives of on-call work when on stand-by through experience (refer to section 5.4.2 Theme 2: Stand-by (1 1) Causes). It is hypothesised that:

hypothesis 16. sleep quantity when on stand-by will be affected by on-call experience (years working on-call)

hypothesis 17. satisfaction with amount of sleep when on stand-by will affected by on-call experience (years working on-call)

hypothesis 18. sleep quality when on stand-by will be affected by on-call experience (years working on-call)

hypothesis 19. restfulness after sleep when on stand-by will affected by on-call experience (years working on-call)

hypothesis 20. fatigue when on stand-by will be affected by on-call experience (years working on-call)

hypothesis 21. anxiety when on-call (as a composite score of anxiety regarding expecting the phone to ring, not knowing when and if you will get a call, and the call itself) will be will be affected by experience (measured through number of years working on-call)

Interviewees in Study 1 have identified their social and family life as being very affected when working on-call (refer back to section 5.4.2 Theme 2: Stand-by, (3) Family and Social for more details). Sleep research investigating the effects of extended wakefulness has shown that wakefulness beyond around 16h leads to both performance deficits and is a cause of sleepiness (Dorrian et al., 2011; Van Dongen, Maislin, et al., 2003). Therefore it is hypothesised that:

hypothesis 22. satisfaction with the amount of time on-call work leaves for life (a composite score of satisfaction with amount of time for hobbies, friends, family, and self) will be significantly different between the different lengths of ‘the longest consecutive period working on-call without sleep’

As identified in Study 1 the management of on-call work in relation to *normal* working hours allows for on-call workers to be rostered to work on-call when on a rostered day off (e.g. weekends) and when on annual leave. Interviewees identified anxiety and well-being as being very affected by this due to never really ‘switching off’ (refer to section 5.4.6 Themes 6, 7 & 8: On-call arrangements, Management of on-call work, & Organisational culture, (1 4) Rest days for more details). It is hypothesised that:

hypothesis 23. anxiety (as a composite score) levels when on-call will be significantly different when ‘being required to work on-call when on leave’ or not

hypothesis 24. anxiety (as a composite score) when on-call will be significantly different when being ‘required to work when on a rostered off day’ or not

hypothesis 25. well-being (as a composite score of fatigue, stress, general well-being, satisfaction with amount of free time for social and family life) when on-call will be significantly different when ‘being required to work on-call when on leave’ or not hypothesis 26. well-being (as a composite score) when on-call will be significantly different when being required to work on a rostered off day or not

Interviews from Study 1 also identified that the main way on-call work impedes their lives is through the amount of time required for work. This is true even when only on stand-by through the need to always be contactable. When actually receiving callouts this demand is even greater and actively steals time for all facets of personal life (refer to sections 5.4.2 Theme 2: Stand-by, (1 2) Consequences and 5.4.4 Theme 4: Responding to callouts, (3) Family and Social for more details). It is, therefore, hypothesised that:

hypothesis 27. satisfaction with on-call arrangements will be affected by the satisfaction with the amount of free time for hobbies

hypothesis 28. satisfaction with on-call arrangements will be affected by the satisfaction with the amount of free time for family and social life

hypothesis 29. satisfaction with on-call arrangements will be affected by the satisfaction with the amount of free time for self

Shiftwork research investigating the effects of age has found some support that older workers can find it harder to work shifts (e.g. Costa & Di Milia, 2008; Harma, 1996; Pires et al., 2009). Age was also mentioned in Study 1 where a number of interviewees mentioned struggling more with on-call work as they get older. As such, it is hypothesised that:

hypothesis 30. quality of sleep when not on-call will be significantly different between the different age groups

hypothesis 31. quality of sleep when on stand-by will be significantly different between the different age groups

hypothesis 32. quality of sleep when receiving callouts will be correlated with age groups

Receiving callouts can be expected to disrupt sleep which is the key human biological function affected by on-call work. Fatigue (e.g. Bonnet, 1985; Bonnet & Arand, 2003; Stepanski, Lamphere, Badia, Zorick, & Roth, 1984), alertness (e.g. Martin et al., 1996; Powell et al., 1999), and stress (e.g. Bennett et al., 1999;

Mcnamara et al., 2006; I. Smith & Shneerson, 1995) are but a few of the factors affected by reduced or impaired sleep. In alignment with this research, interviewees in Study 1 also identified sleep as being affected by on-call work, and much more so when receiving call-outs than when on stand-by (refer to section 5.4.4 Theme 4: Responding to callouts for more details). It is therefore hypothesised that:

On-call event factors

hypothesis 33. sleep quantity will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call

hypothesis 34. satisfaction with the amount of sleep will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call

hypothesis 35. sleep quality will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call

hypothesis 36. restfulness after sleep will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call

hypothesis 37. fatigue after sleep will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call

On-call research has identified an association between on-call work and impaired cognitive performance and mood (e.g. Saxena & George, 2005; Wesnes et al., 1997). This could be related to sleep fragmentation, where research has shown that periodic sleep disruption directly affects mood, motivation, and psychomotor performance on a number of tasks including tasks involving short term memory, reaction time, and vigilance (e.g. Bonnet, 1985; Bonnet & Arand, 2003; Stepanski, Lamphere, Badia, Zorick, & Roth, 1984). Similar findings have been identified through sleep inertia research where a broad range of tasks, including reaction times, steadiness and coordination, visual perception tasks, memory tasks, logical reasoning tasks, and several cognitive tasks where found to be deteriorated due to sleep inertia (Tassi & Muzet, 2000). As a result, mood, motivation, and performance can be expected to be differently affected when solely providing advice over the telephone (potentially tasks that require more logical reasoning and short term memory) and when being required to attend site as also mentioned by interviewees in Study 1 (refer to section 5.4.3 Theme 3: Receiving callouts, (6) Performance and Mood for more details) so it is hypothesised that:

hypothesis 38. decision making as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation

hypothesis 39. attention as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation

hypothesis 40. alertness as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation

hypothesis 41. speed of work as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation

hypothesis 42. quality of work as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation

hypothesis 43. mood will be significantly different between being called-out and required to attend site and solely providing a telephone consultation

hypothesis 44. motivation will be significantly different between being called-out and required to attend site and solely providing a telephone consultation

From Study 1 it is expected that both the number of calls and the percentage of calls that disrupt sleep are the main callout associated factors that lead to negative consequences (refer to section 5.4.3 Theme 3: Receiving callouts for more details). It is therefore hypothesised that:

hypothesis 45. fatigue when on-call will be statistically different between different number of callouts hypothesis 46. fatigue when on-call will be statistically different between different percentage of callouts after going to sleep

hypothesis 47. stress when on-call will be statistically different between different number of callouts

hypothesis 48. stress will be statistically different between different percentage of callouts after going to sleep

hypothesis 49. performance when on-call and required to attend site will be statistically different between different number of callouts

hypothesis 50. performance when on –call and required to attend site will be statistically different between different percentage of callouts after going to sleep

hypothesis 51. performance when on-call and providing advice over the telephone will be statistically different between different number of callouts

hypothesis 52. performance when on-call and providing advice over the telephone will be statistically different between different percentage of callouts after going to sleep

hypothesis 53. quality of sleep when on-call will be statistically different between different number of callouts

Difficulties in falling back asleep after being called-out were identified by interviewees in Study 1 mainly due to ‘thinking about decisions’ which in turn affects sleep quality and quantity (for more details refer to section 5.4.3 Theme 3: Receiving callouts, (1) Sleep Disruption). Sleep inertia research has also identified that sleep inertia can last from one minute to four hours but that in the absence of major sleep deprivation, it rarely exceeds 30 minutes and that falling back asleep after this is difficult (Balkin & Badia, 1988; Hofer-Tinguely et al., 2005; Tassi & Muzet, 2000). Based on this, it is hypothesised that:

hypothesis 54. quality of sleep when on-call will be statistically different between the different percentage of calls that lead to being awake for more than 30 minutes after receiving a callout

hypothesis 55. well-being (as a composite score of fatigue, stress, general well-being, satisfaction with amount of free time for social and family life) when on-call will be statistically different between the different percentage of calls that lead to being awake for more than 30 minutes after a callout

Torsvall & Akerstedt, (1988) when investigating on-call work in ship engineers found that low sleep quality was caused by the expectation of hearing alarms. Further support for this was found in Study 1 where interviewees identified anxiety as one of the main causes for poor sleep quality (refer to section 5.4.2 Theme 2: Stand-by, (1) Anxiety for more details). It is hypothesised that:

hypothesis 56. sleep quality when on stand-by will be affected by anxiety (as a composite score)

Sleep research has identified a large number factors associated with sleep. For example, a negative association between sleep disturbance and psychological well-being, including clinical depression has been consistently identified by research (e.g. Chu & Richdale, 2009; Goyal, Gay, & Lee, 2007, 2009; Sloan, 2008). Similar results have been found with regards to fatigue (Åkerstedt & Wright, 2009), stress (Giovanni Costa, 2003), and many other unwanted outcomes. It is, therefore, hypothesised that:

hypothesis 57. well-being (as a composite score) when on-call will be affected by sleep quality

hypothesis 58. well-being (as a composite score) when on-call will be affected by sleep quantity

6.4 Method

A digital format questionnaire survey was produced to collect data from all 40 Delivery Units across GB. This study was designed as a follow up study to the exploratory interviews of Study 1 and aimed to verify the generality of the findings of Study 1 and provide further details into the idiosyncrasies of factors identified, such as timing and amount of calls, stress and fatigue. The same data identified managers as being more at risk from on-call work than frontline staff. As a result the target population for this study were all managerial level on-call Infrastructure Maintenance staff members.

A questionnaire survey was chosen as it was deemed the most effective way to explore the generality of the data collected in Study 1 and because it would allow for large quantities of data to be collected quickly across the company. It was decided that the survey would be held online on a Network Rail platform as this would facilitate the access of staff to the survey and would give participants the freedom to respond at any time they wished. The questionnaire was constructed in three separate sections designed to assess different aspects of the on-call scheduling system of work. Section one focused on on-call arrangements, section two on the impacts of on-call work versus non on-call work, and section three assessed the overall views of participants regarding on-call work. A fourth section assessed the demographic factors thought to potentially have an influence on on-call work. For more details refer to Chapter 4 where methods are discussed in greater detail. The full questionnaire is presented in Appendix A - On-call questionnaire survey.

6.4.1 Selection method

Working on-call and being of a managerial position in Infrastructure Maintenance were the only two requirements of participation. All participation was voluntary and anonymous and all data collected were treated with strict confidentiality in accordance with University of Nottingham Ethics procedures. An invitation of participation was sent-out across the Infrastructure Maintenance organisation via email to all managerial level on-call workers. As a result, the sampling for this work was non-probabilistic (Robson, 2002).

6.4.2 Analysis

All data were compiled directly from the Ergotools website where the survey was hosted directly into a Microsoft Excel spreadsheet. Upon completion of the survey the data were then transferred to the Statistical Package for Social Sciences (SPSS) and prepared for analysis using the procedure described below. All data analysis was performed using SPSS version 20.0.

Stage 1: Data collection: All data were collected via an on-line questionnaire survey during a period of six weeks.

Stage 2: Preparation of data for analysis: All recorded data were transferred to SPSS and scanned initially for mistakes and errors and these were corrected when possible. When correction was not possible these data were transformed into missing data so that it would not distort results.

Stage 3: Descriptive statistics: All variables were analysed, a description of the results found was produced and the differences found between the different on-call scenarios were analysed and described.

Stage 4: Multivariate statistics: At this stage the data were tested for relationships between the different factors and for the effects different factors have on the effects identified in the on-call framework.

6.5 Results

In keeping with the structure of the questionnaire, the data were analysed and reported here based primarily on the three main sections of the survey; *On-call arrangements, Overall views,* and *Impacts of working on-call*. The main results sections are therefore arranged under these same main headings, within each main section results are then presented per factor and then, when justified, by on-call scenarios. This allowed the researcher to maintain a functional logic to the presentation of results where functional information data is reported first i.e., *On-call arrangements*, followed by data that express general view regarding the system (e.g. *General impact of working on-call),* and finally data which reflect the impacts of working on-call (e.g. *Sleep disruption*).

6.5.1 Sample description

At the end of the data collection period 479 completed questionnaires had been returned out of a population of around 800 managerial on-call workers (60% response rate). Data regarding the role of participants were not collected. Respondents cover all 11 routes with a good distribution of responses from all areas apart from Wales with only 17 respondents (3.64% response rate). For detailed response rates per route see Appendix E – Responses per Route. Respondents have worked on-call for an average of 12 years (SD = 8.15) with a minimum of 2 months and a maximum of 41 years, with 75% having worked on-call for 18 years or less. Most respondents (66%) have worked in the rail industry for 20 years or more, have been in their current position between one and five years (47%), and are between 45 and 56 years of age (48.0%). The great majority of respondents are male (99%), work on average 48 hours per week including overtime (SD = 7 hours and 18 minutes) with 79% of them working 50 hours or less. Of the remainder, who work over 50 hours per week, 6.7% work on average 55 hours per week and 7.1% work on average 60 hours per week.

6.5.2 On-call arrangements

Respondents work under a large number of different on-call arrangements. In this section we discuss the organisation of the different on-call scheduling systems that respondents across GB work within, the variability and preparation of rosters and identify the responsible person or persons to deal with issues that may arise with rosters. Reasons for working on-call and how common on-call work is are also discussed.

6.5.2.1 Roster arrangements

On-call work is performed mainly in blocks of weeks, where the most common system is to be on-call for a period of 24 hours for seven consecutive days followed by a number of weeks ‘off-call’. As expected (hypothesis 1), the great majority of respondents have an on-call roster (97.1%) and most rosters are arranged in the format of 1 week in *n* weeks (94.1%) with 88.9% of these being arranged between 1 week in 2 weeks and 1 week in 10 weeks.

A great variability of on-call rosters was identified throughout GB with 45 different on-call rosters reported, although, of these, 28 were reported by individual respondents (e.g. “just cover when staff is on annual leave”, “every Monday plus one weekend [Fri, Sat, Sun] in 4 weeks”). Slow rotating rosters, with a period longer than three weeks between shifts, represent the great majority of worked rosters (80%). As discussed in the previous chapter, faster rotation rosters (e.g. 1 week in 2) are not considered workable by most interviewed on-call staff as they do not allow for enough rest or allow for a good work-life balance. Nonetheless, there are 110 respondents (23%) working under fast rotating rosters i.e. 1 week in 2 weeks, 2 weeks in *n* weeks, and 1 week in 3 weeks. Figure 6.1 shows a graphic representation of the distribution where rosters with less than 1.0% of responses were collapsed into the category *other.*

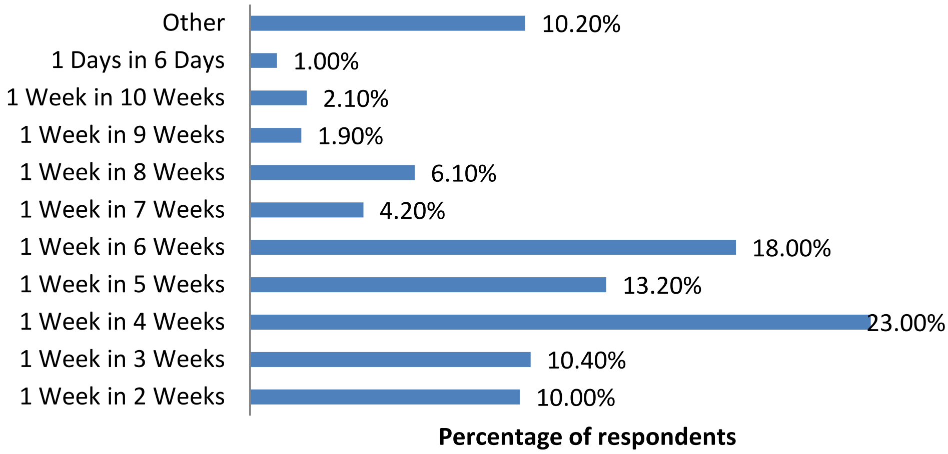


Figure 6.1- Distribution of respondents per on-call frequency

For most respondents (48.2%) on-call rosters are arranged with more than six months notice. For a small minority (2.9%) rosters are arranged with one week or less and the remaining 48.1% are distributed between two to three weeks notice (6.3%), four to six weeks notice (10.9%), nine to 12 weeks notice (10.4%), 13 to 25 weeks notice (13.2%)[18]. Although on-call rosters seem to be prepared with several weeks notice, respondents are still required, on average, to sometimes change their on-call rosters on short notice (M=2.24, SD=1.01; 1 = almost never, 5 = almost always).

As predicted by hypothesis 4, for 91% of respondents, on-call arrangements do not match up with their working hours' arrangements and, as such, there is the possibility for them to be rostered to work on-call whilst on rostered days off or when having a rostered weekend off. Similarly, this situation is also possible with regards to annual leave with 79.3% of respondents stating it is possible to be on annual leave and still be rostered to work on-call (hypothesis 3). Respondents were given three, not mutually exclusive, options (*a replacement is arranged, swap the shift with a colleague, required to work)* to describe how these situations are dealt with. For most respondents (84.1%) no replacement is arranged with the responsibility to arrange cover in these situations falling on the member of staff himself (90%) with only 6.5% of respondents stating it is their managers' responsibility to arrange cover. The remaining 3.5% of respondents were either unsure of how the situation would be dealt with or stated the situation is dealt with both by themselves and their managers. In general it is left to the individual to either work on-call whilst on leave or on a day

[18] A total of 8.1% of respondents further claimed this question did not apply to them although only 2.9% of respondents claimed not having an on-call roster.

off (42%) or attempt to swap the shift with a colleague (55.9%). Figure 6.2 shows a graphical representation of these results. When asked how often they were required to cover a colleague's shift (1 = almost never, 5 = almost always), on average respondents deemed these situations to be moderately frequent (M=2.90, SD=1.01).

A number of respondents (80 respondents or 16.7%) also described specific ways to deal with these situations (e.g. "annual leave would be covered by a co-worker but days off can only be swapped if I can find a replacement") which further strengthens the idea that on-call arrangements are mainly left for staff to manage.

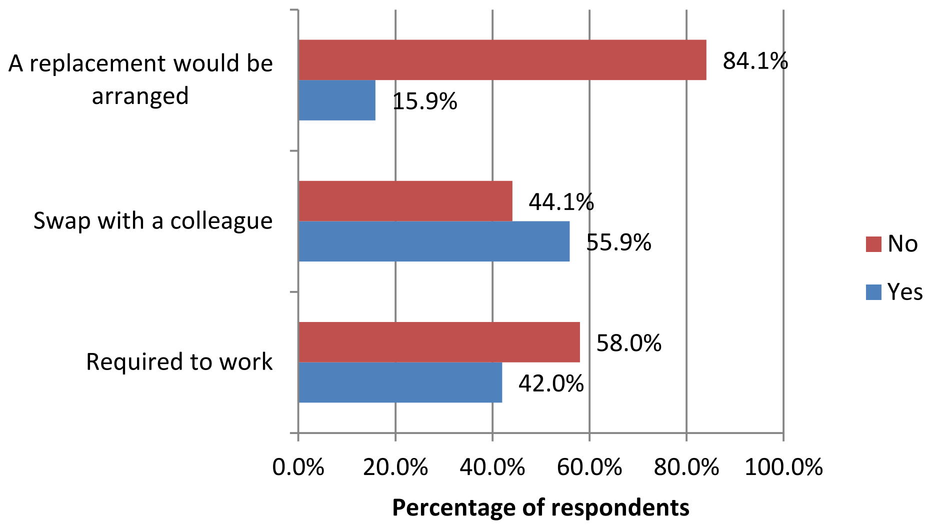


Figure 6.2 - Distribution of ways to deal with on-call work when on leave or day off

6.5.2.2 On-call shift length and amount

The majority of respondents (72%) worked on-call for seven days or less in the month previous to responding to the survey. However, when asked for the maximum amount of days worked on-call in the past year, the most common response was 14 consecutive days on-call (33.4% respondents). Moreover, the most common amounts of consecutive days working on-call spike at every multiple of seven with 14 consecutive days being the most common, followed by seven (20%), then 21 days (10%) and finally 28 days (4.2%). Unexpectedly, 7.5% of staff (36 respondents) state they have worked on-call for 30 days or more in the last year and there are nine respondents that choose to be always contactable and, as such, have worked on-call for the duration of the year.

Respondents' longest amount of time working on-call without sleep is very high with only 7.9% of respondents claiming their longest period of on-call work, including their usual shift hours, is between 8 hours and 12 hours. The great majority of workers (93.1%) have at least in one occasion worked for periods longer than 12 hours when on-call and 23.6% have worked for periods longer than 24 hours. Figure 6.3 presents a visual representation of these results.

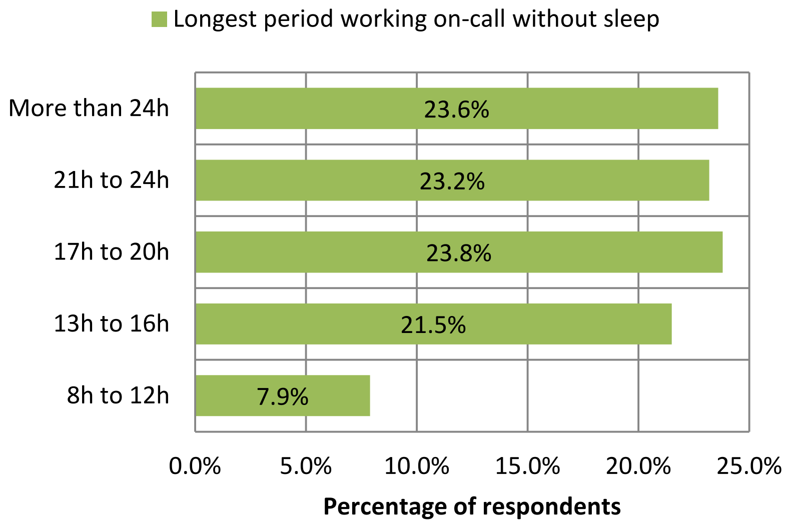


Figure 6.3- Graphical representation of longer period of on-call work including usual shift

6.5.2.3 Reasons to work on-call

As expected (hypothesis 2), from the data collected from the interviews, the great majority of respondents are required to work on-call (97.2%) and feel they are also required to maintain their normal working hours (96.7%). In agreement with this the hypothesis 5main reason to work on-call (1 = Not a reason for me, 5 = Very much a reason for me) is because it is part of the job (M = 4.54, SD = 1.15), followed by the wish to help (M = 3.02, SD = 1.49). As predicted (hypothesis 5), higher rates of pay (M = 1.64, SD = 1.17) were not a reason to work on-call, and the wish to know what is happening as a reason to be on-call (M = 2.42, SD = 1.38) was only a moderate reason.

6.5.3 Overall views

6.5.3.1 General impact of working on-call

In general the impact respondents feel on-call work has on them is large (M = 3.57, SD = 1.06; 1 = no impact, 5 = very large impact) with 56.6% of respondents feeling on-call work has a large or very large impact on them and only 17.5% feeling it has a low or very low impact. On average respondents also feel their partners are unhappy about their requirement to work on-call (M = 2.26, SD = 1.08; 1 = extremely unhappy, 5 = extremely happy). In effect, only 13.3% of respondents feel their partners are happy or extremely happy with their on-call work. Of all the respondents, only 5.6% did not have a partner.

Additionally, if given the choice, respondents would prefer not to have to work on-call (M = 1.96, SD = 1.28) with at 56% stating they would definitely not work on-call if given the choice (1 = definitely not, 5 = definitely yes).

6.5.3.2 Impacts of on-call work on well-being

On-call respondents rated well-being indicators (fatigue, stress, general well-being, family life, and social life) as being significantly different from when not on-call. These results are in accordance with hypothesis 8, hypothesis 9, hypothesis 10, hypothesis 11, and hypothesis 12 which predicted that well-being indicators will be significantly different when working on-call and not working on-call. Table 6.2 presents the results of the t-tests conducted to assess these.

Table 6.2- Well-being impact from 'normal' work and on-call work (1 = no impact, 5 = very large impact).

Factor		On-call	Not on-call	T-test result
Fatigue	M	**3.39**	**2.02**	t(478) = 23.355***
	SD	1.100	0.956	
Stress	M	**3.35**	**2.16**	t(478) = 20.292***
	SD	1.204	1.029	
General well-being	M	**3.18**	**1.97**	t(478) = 21.545***
	SD	1.114	0.955	
Family life	M	**3.52**	**1.95**	t(478) = 23.816***
	SD	1.159	1.024	
Social life	M	**3.66**	**1.95**	t(478) = 25.978***
	SD	1.153	1.018	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

It was also found that when on-call, around 50% of respondents feel on-call work has a large or very large impact on their fatigue levels, stress, and family life. A further 41.4% of respondents feel on-call work has a large or very large impact on their general well-being, and 67.4% feel their social life is largely or very largely affected. In contrast, when not on-call at least 66% of all respondents state their work does not affect any of the five well-being indicators used.

6.5.3.3 Satisfaction

It is predicted (hypothesis 13) that 'satisfaction with on-call work will be significantly different from satisfaction with the job in general'. To assess this hypothesis a t-test was performed and results are presented in Table 6.3.

Table 6.3 - Satisfaction with on-call work versus job ion general (1 = not satisfied at all, 5 = very satisfied)

Factor		On-call	Job in general	t-test
Satisfaction	M	**3.55**	**2.82**	t(478) = 11.465***
	SD	1.11	1.24	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

These results support the hypothesis. What is more, 55.9% of respondents feel satisfied or very satisfied with their general job whilst only 31.5% feel satisfied or very satisfied with their on-call work arrangements. When asked about satisfaction regarding specific factors, participants reported feeling unsatisfied with the amount of time on-call work leaves them for their hobbies and activities, family and friends and for themselves (M= 2.62, SD = 1.27; M = 2.57, SD = 1.26; M = 2.65, SD = 1.25, respectively).

6.5.4 Sleep

The impact on sleep indicators when not on-call, when on stand-by, and when receiving calls, was assessed through five sleep indicators. These were: quantity of sleep, how respondents feel regarding the amount of sleep they get, sleep quality, how rested respondents feel after sleep, and how fatigued respondents feel after sleep.

6.5.4.1 Sleep and on-call scenarios (hypothesis 33, hypothesis 34, hypothesis 35, hypothesis 36, and hypothesis 37).

Repeated measures ANOVA with Greenhouse-Geisser correction determined that all sleep indicators tested (sleep quantity, satisfaction with amount of sleep, sleep quality, restfulness after sleep, fatigued after sleep) were found to be statistically different in the three on-call scenarios (hypothesis 33, hypothesis 34, hypothesis 35, hypothesis 36, and hypothesis 37). There was a statistically significant difference found regarding sleep quantity, sleep quality, the restorative effect of the sleep period, how rested, and how fatigued respondents feel after sleep for each of the three scenarios. Planned comparisons revealed that all three scenarios were significantly different from each other with $\rho < 0.001$. These results are shown in Table 6.4.

Table 6.4 - Sleep indicators per on-call scenario

Factor		Not on-call	Stand-by	Receiving calls	ANOVA
Quantity of sleep per night	M	**7h14min**	**6h40min**	**4h30min**	F(1.686, 791.542) = 1424.005***
	SD	55min	40 min	1h14min	
Satisfaction amount of sleep	M	**4.11**	**3.42**	**2.01**	F(1.835, 877.328) = 964.492***
	SD	0.927	1.102	1.01	
Quality of sleep	M	**4.13**	**3.23**	**2.04**	F(1.824, 871.727) = 933.600***
	SD	0.852	1.01	1.051	
How rested after sleep	M	**4.05**	**3.25**	**1.97**	F(1.828, 873.759) = 928.821***
	SD	0.841	1.03	1.016	
Fatigued after sleep	M	**2.51**	**2.82**	**3.34**	F(1.318, 628.993) = 67.545***
	SD	1.220	1.01	1.354	

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

6.5.4.2 Sleep disruption

Around 50% of respondents receive on average four or less callouts per on-call period (usually one week). Of these, 20.7% state they receive on average one to two callouts. For 19.8% of respondents this number is higher with five to six callouts per period on average. The number of respondents receiving more than six callouts on average is smaller with 9.6% receiving between seven and eight callouts on average and 8.4% receiving nine to 10 callouts. Even so, the number of respondents that feel they receive on average more than 10 callouts per on-call period is surprisingly high at 14.4%.

Regarding the time of callouts, 56.5% of respondents claim that at least 50% of all callouts take place after the respondents had gone to sleep, with 23.3% of respondents claiming most of their callouts (76% to 100%) take place after they have gone to sleep[19].

In addition, most respondents (48.7%) feel the majority of callouts (76% to 100%), which take place when respondents are already asleep, prevent sleep for at least 30 minutes afterwards. Figure 6.4 shows a graphical representation of these results.

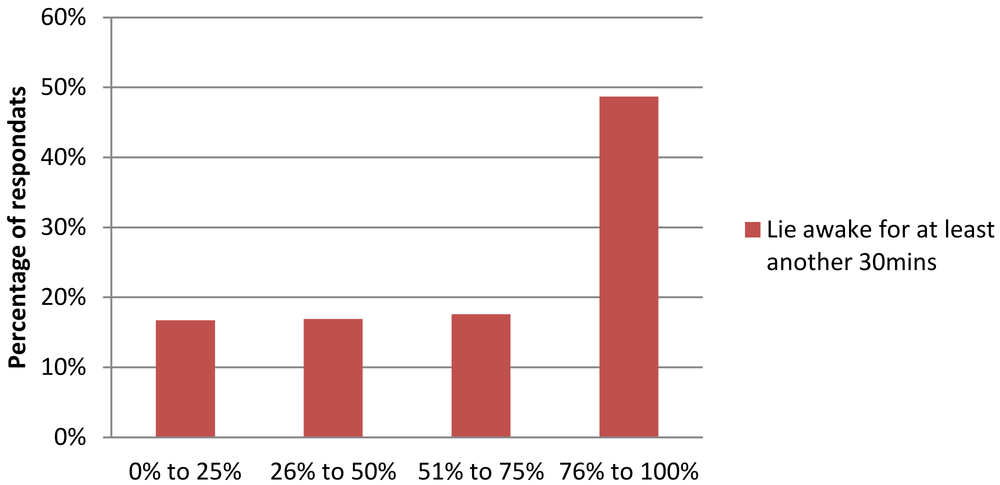


Figure 6.4 – Percentage of callouts that prevent sleep for at least 30 minutes

A large number of respondents (66.2%) believe there is a worst time to be called-out. Respondents were able to specify the worst time to be woken up either in terms of how long after they had gone to sleep (e.g. 2 hours), or in terms of the specific time when they received the callout (e.g. 2300 hours). Of those that believe there is a worst time to be called-out, 83.9% (267 respondents) feel the worst time to be called-out is a specific number of hours after falling asleep, and the remainder 16.1% (52 respondents) that it is worse to be awoken at a specific time of day.

For those respondents who feel it is worse to be awoken a number of hours after falling asleep it is clear that the majority of the respondents (95.1% or 254 respondents) feel it is much more disruptive to be woken up between zero and four hours after falling asleep. Figure 6.5 below presents the distribution of these results.

[19] A graphic representation of these results can be found in Appendix F – Percentage of callouts when already asleep.

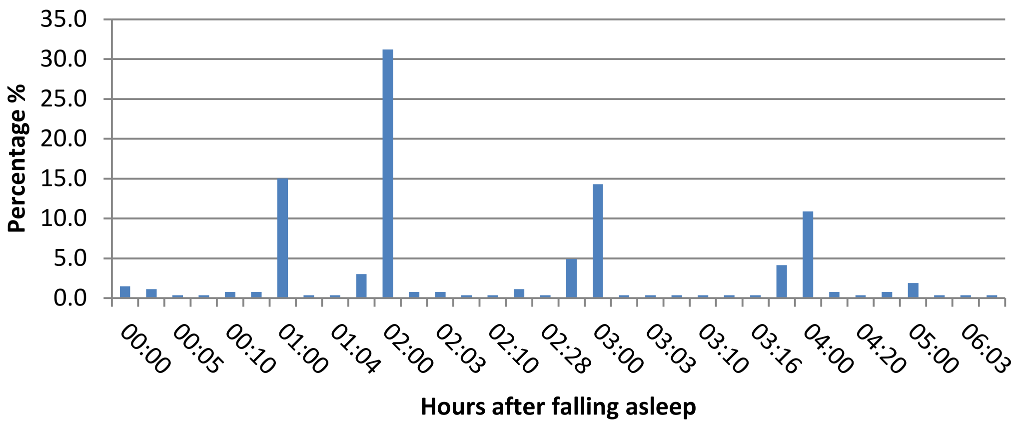


Figure 6.5 - Worst time to be awaken after number of hours after having gone to sleep in percentage

For the respondents who feel it is worse to be called out at specific times of day (52 respondents), 2300 hours was the most commonly mentioned time with 18.8% of responses. These answers are in line with those of respondents that feel there are specific times that are more disruptive than others if we assume that most respondents go to sleep between 22h00 and 23h00. If this is the case, these responses equate to those of respondents that feel they experience more disruption a number of hours after falling asleep, namely, between zero and four hours. Figure 6.6 below presents a graphical summary of these results.

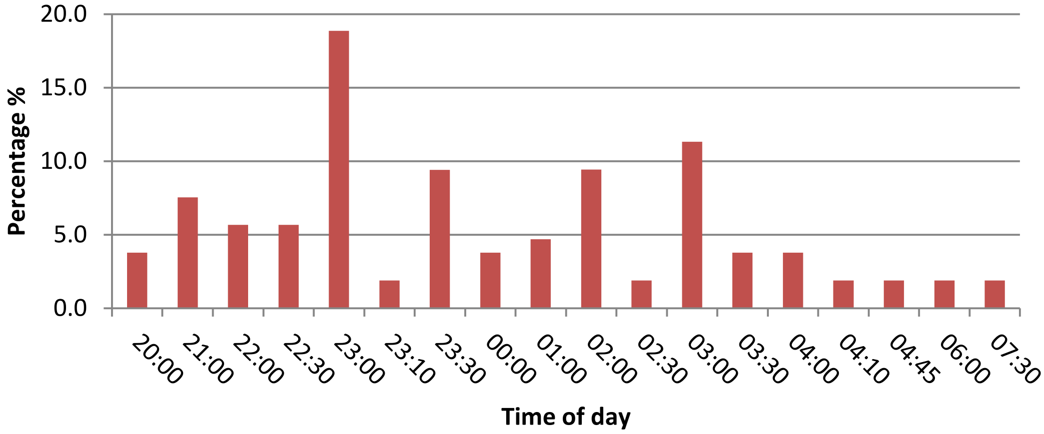


Figure 6.6 - Worst time to be awaken per time of day in percentage

6.5.5 Performance when on-call

The impact felt on perceived performance and perceived ability to conduct on-call duties when providing consultations over the telephone compared with being required to attend on site was assessed through five general performance indicators: decision making ability, attention, alertness, speed of work, and quality of work. It is predicted by hypothesis 38, hypothesis 39, hypothesis 40, hypothesis 41, and hypothesis 42 that performance indicators will be significantly different between being called-out and required to attend site and solely providing a telephone consultation. To test this, t-tests were performed for the five performance indicators when required to attend site and when providing a telephone consultation.

Results show that respondents feel their performance is, on average, more affected when responding to callouts over the telephone than when required to attend site to deal with the fault. This supports the hypotheses with the exception of hypothesis 41 as statistically significant differences were found for four of the five performance indicators with speed of work being the only indicator where no differences were found. These results are shown below in Table 6.5.

Table 6.5 - Telephone consultation and attending site performance ('How much are the following affected', 1 = not at all, 5 = very much so).

Factor		Telephone consultation	Attending site	t-test
Decision making	M	**2.53**	**2.38**	t(478) = 3.851***
	SD	1.127	1.147	
Attention	M	**2.60**	**2.48**	t(478) = 3.217***
	SD	1.147	1.148	
Alertness	M	**2.74**	**2.65**	t(478) = 2.178**
	SD	1.147	1.193	
Speed of work	M	**2.67**	**2.67**	t(478) = 0.114
	SD	1.078	1.127	
Quality of work	M	**2.47**	**2.39**	t(478) = 2.150**
	SD	1.082	1.096	

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

6.5.6 Mood and Motivation

Together with experiencing deteriorated performance, interviewees in Study 1 also reported experiencing deteriorated mood when receiving callouts. During the interviews it was not made clear if this was an effect that varied when providing a telephone consultation and when attending a fault on site. To assess the generality of this effect, respondents were asked to rate how their mood and motivation to work were affected in both these situations.

When receiving a callout and providing guidance over the telephone, on average, respondents feel their mood is moderately affected (M = 3.10, SD = 1.24; 1 = not at all, 5 = very much so). Of these, 33.4% feel their mood is not affected, or not affected at all, whilst 39.6% feel their mood is affected or very affected. When receiving a callout and attending site, on average, respondents feel their mood is moderately affected (M = 3.24, SD = 1.28; 1= not at all, 5 = very much). There is, however, a large variation of responses (C_v = 0.40) with each score taking around 20% of responses. Score "1 - not at all" is the exception with only around 10% of responses. Moreover, around 45% of respondents feel their mood is affected, or very affected when required to attend a fault when responding to a callout.

The motivation of respondents to work when receiving a callout and not being required to attend site is only slightly affected on average (M = 2.67, SD = 1.21). This is not the case for around a quarter of respondents (25.3%) who feel their motivation is affected or very affected when providing assistance on the telephone after a callout. A further 46.3% feel their motivation is not affected or not affected at all. Respondents' motivation to conduct work when required to attend site, on average, is not affected (M = 2.64, SD = 1.27) with 74.1% of respondents feeling their motivation is either moderately affected or not affected. Nonetheless, 25.9% of respondents feel their motivation is impaired or severely impaired. Details on these scores are presented in Figure 6.7.

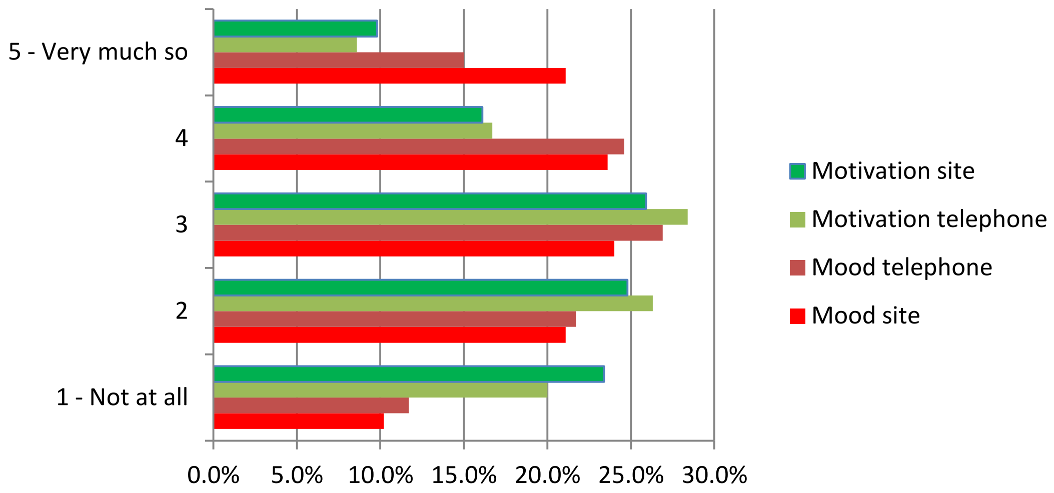


Figure 6.7 - Mood and motivation responses per callout scenario

No statistically significant differences were found between the level of motivation when being called-out and only providing a telephone consultation or when also being required to attend the fault. The mood with which respondents attend the fault, however, is significantly worse when respondents are solely required to provide advice over the telephone. Table 6.6 shows a summary of results. These results support hypothesis 43 but not hypothesis 44.

Table 6.6 - Motivation and mood for telephone consultation and attending a fault (1 = not at all, 5 = very much so).

Factor		Telephone consultation	Attending site	T-test
Motivation	M	**2.67**	**2.64**	t(478) = 0.974
	SD	1.127	1.147	
Mood	M	**3.10**	**3.24**	t(478) = 3.707***
	SD	1.147	1.148	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

6.5.7 Stress

Stress, and anxiety in particular, as a specific type of stress, were identified by interviewed maintenance staff in Study 1. When on-call and specifically when on stand-by, anxiety was identified as one of the main issues for on-call workers. To assess the generality of the causes of anxiety identified during Study 1, questionnaire respondents were asked to rate each of them.

When not on-call, respondents' stress was found to be low on average ($M = 2.15$, $SD = 1.05$; 1 = not at all, 5 = very much). Plus, at least 67% of respondents do not feel stressed when not working on-call. As expected this score has a good correlation with the general impact of 'normal' work on stress assessed as part of the general impact of working on-call on well-being ($r = 0.638$, $\rho < 0.001$). For further details see section 6.5.3.2 Impacts of on-call work on well-being.

On average, when working on-call, respondents' stress is moderately high ($M = 3.47$, $SD = 1.22$, 1 = not at all, 5 = very much), with at least 75% of respondents feeling their stress level is moderate to very high when on-call. Here, the correlation with the general impact of on-call work on stress, assessed as part of the general impact of working on-call on well-being, is also good ($r = 0.742$).

As expected, two reasons behind feeling anxious when working on-call (1 = not at all, 5 = a very large extent), are expecting a callout ($M = 3.26$, $SD = 1.36$) and not knowing when a callout will occur ($M = 3.25$, $SD = 1.36$). This is in accordance with hypothesis 6 and hypothesis 7. Respondents feel that both cause a moderate amount of anxiety on average, and around 50% of respondents claim these account for a large extent or a very large extent of their anxiety when on-call. Additionally, on average, respondents consider the call itself as a moderately low stressor ($M = 2.59$, $SD = 1.26$).

A number of respondents (15 respondents) further mentioned specific situations they feel are particularly anxiety provoking, for example, "bad weather", or "very anxious that the rest of my family will be woken up if the phone rings". All reasons mentioned are presented in Table 6.7.

Table 6.7 - List of anxiety causes for respondents

Stressors
“Bad weather if on call”
“Constant eye on BB for Asset Incidents”
“Constant higher management interventions”
“Disturbing sleeping partner”
“Especially when it is control’s number on your phone that is dialling you.”
“Having to check for e-mails every few minutes day and night as we get hundreds of them all day and night and expected to read them all to spot problems rather than control calling us”
“I feel anxious knowing that I could get a call just as I intend to rest.”
“Knowing there will be a lack of staff on shift thus being 'expected' to cover for this and attend 'first line' faults!”
“More anxious if going out”
“Phone calls that disrupt my personal time because control are unable to manage a situation”
“The worst thing is being woken to find out that control have not bothered to check out the fault first and it not even being on my area. This is really annoying and happens frequently.”
“Very anxious that the rest of my family will be woken up when the phone rings”
“Whether you have made the correct engineering decision. Especially when dealing with safety.”
“When at work”
“You get a lot of call from other departments”

6.5.7.1 Sub-groups

From data collected during Study 1 it was thought that different socio-demographic profiles could be identified in the data that could then be used to conduct further analysis. If this was indeed the case, these sub-groups could represent clusters of individuals that differ from each other in such a way that could then be tested across the pool of on-call outcomes (or impacted) associated factors. If such groups are found in the data it would indicate that specific characteristics of the socio-demographic profiles would be grouped together and could be used to test the influence of experience, for example, on the factors being studied.

To test for the existence of such profiles a Multiple Correspondence Analysis (MCA) was performed on the socio-demographic indicators used in the survey i.e. age group, number of years in the rail industry, number of years working on-call, gender and number of years in current position. The identification of the number of dimensions in analysis was performed using the inertia criterion, introduced by Benzécri (1977) and recommended by Tenenhaus & Young (1985) where inertia score larger than 0.2 should be considered. Inertia scores reveal that two dimensions would offer the best solution with one dimension accounting for 52% of variance, and two for 90%.

The analysis of the discrimination factors, however, reveal that all the factors under analysis did not discriminate and are in fact very closely related in the two dimensions identified (Greenacre, 1984; Hair, Black, Babin, Anderson, & Tatham, 2006). As a result, only one dimension could be identified and, as such, no significant social-demographic groups could be identified it the data. These findings did not support the existence of sub-groups of individuals that are separated from the remainder due to their socio-demographic characteristics.

Similarly, it was also thought that different groups could be identified with regards to on-call arrangements that would represent a number of associated ways of arranging on-call work. To assess the existence of such groups a second Multiple Correspondence Analysis (MCA) was performed on the relevant on-call arrangements factors used in the survey, i.e. on-call frequency, notice period of on-call roster, Delivery Unit, number of hours worked per week, number of days worked on-call last month, maximum number of days ever worked on-call, possibility to be rostered when on leave, possibility to be rostered when on a day off, on-call voluntary versus mandatory, and need to maintain normal working hours. Once again the analysis revealed that all the factors were closely related and no on-call arrangement sub-profiles could be identified in the data (Greenacre, 1984; Hair et al., 2006).

Much the same with regards to socio-demographic indicators and on-call arrangement factors, it was also thought that there could be different profiles regarding the feelings towards on-call work. A third Multiple Correspondence Analysis (MCA) was performed with factors associated with feelings towards on-call work, i.e. prefer to work on-call if not required to, how does the partner feel about on-call work, satisfaction with on-call work, and satisfaction with time left for family and social activities. Here also, the test revealed only one dimension and as such, no sub groups could be identified (Greenacre, 1984; Hair et al., 2006). Similarly, to the previous two multiple correspondence analysis, these results do not support the existence of sub-groups of individuals characterised by the factors used to explore feelings towards on-call work.

6.5.8 Multivariate tests

6.5.8.1 On-call arrangements (hypothesis 14 and hypothesis 15)

To explore the hypotheses that well-being indicators and satisfaction when working on-call will be correlated with speed of roster rotation (slow versus fast rotating rosters as defined by participants in Study 1), Analysis of Variance (ANOVA) were performed (hypothesis 14 and hypothesis 15).

To conduct this analysis, on-call frequency was separated into either slow rotating rosters or fast rotating rosters. This was done based on the results of Study 1, where interviewees indicated what they considered slow and fast rotating rosters. Rosters identified in Study 1 as fast rotating ones (1 week in 2 weeks, 1 week in 3 weeks, and 2 weeks in n weeks) were treated together as a new subset factor - fast rotating rosters. The remaining rosters of the same format (n weeks in n weeks) were also treated together as slow rotating ones. This includes all rosters between 1 week in 3 weeks and 1 week in 10 weeks. Rosters of the format *n* days in *n* days were initially also collapsed into a single subset but due to the small number of cases (11 cases in total) it was decided to remove them from the analysis. For the same reason, the remaining rosters were also removed from the analysis as they were a minority. After recoding, the factor 'on-call frequency' is represented by 25.1% (110 respondents) fast rotating rosters, and 74.9% (328 respondents) slow rotating rosters.

The impact on well-being, defined as a composite well-being score was computed by averaging the well-being indicators (fatigue, stress, general well-being, family life, social life) when on-call (1 = no impact, 5 = very large impact) as all are heavily correlated ($0.551 >= r >= 0.767$). Satisfaction with on-call work was assessed through the satisfaction scale (question 23 in questionnaire).

Using the recoded factors two one-way ANOVAs were performed and no significant differences were found for either well-being or satisfaction with on-call work. Table 6.8 below presents these results.

Table 6.8 - Well-being and satisfaction with on-call work for fast and slow rotating rosters

Factor		*Roster speed* Slow	Fast	ANOVA result
Satisfaction	M	**2.45**	**2.23**	F(1,436) = 1.037
	SD	1.03	1.11	
Well-being	M	**3.29**	**3.09**	F(1,436) = 2.968
	SD	1.02	1.04	

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

6.5.8.2 Implementing factors (hypothesis 16 to hypothesis 31)

To explore the hypothesis that 'anxiety when on-call (as a composite score of anxiety regarding expecting the phone to ring, not knowing when and if you will get a call, and the call itself) will be will be affected by experience (measured through number of years working on-call)' (hypothesis 21), and the hypothesis that sleep indicators (sleep quantity, satisfaction with amount of sleep, sleep quality, restfulness after sleep, fatigued after sleep) will be significantly different between different levels of on-call experience (hypothesis 16, hypothesis 17, hypothesis 18, hypothesis 19 and hypothesis 20), six linear regressions were performed.

On-call experience was assessed through number of years working on-call. The anxiety score is a composite factor constructed from the average scores of the three anxiety questions posed in the survey i.e. "how anxious do you feel regarding, a) expecting the phone to ring? b) not knowing when and if you will get a call? c) the call itself?)". The three factors had a high correlation (0.877 <= r <= 0.920). The response scale varies from "1 = not at all" to "5 = a lot".

Results identified no effect between experience and anxiety or between experience and sleep indicators. This indicates that there is no relationship between experience and the factors at study. Table 6.9 below presents these results.

Table 6.9 – Linear regressions between experience and anxiety, and sleep indicators when on stand-by

Factor	Beta	t-test	R^2
	Anxiety		
Experience	**-0.050**	t(477) = 32.914	0.000
	Sleep quantity		
Experience	**-0.019**	t(474) = 80.161	0.000
	Sleep quality		
Experience	**0.037**	t(477) = 35.697	0.000
	Satisfaction with sleep		
Experience	**0.039**	t(477) = 37.776	0.000
	Restfulness		
Experience	**0.021**	t(477) = 38.698	0.000
	Fatigue		
Experience	**-0.012**	t(477) = 34.741	0.000

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To test the hypothesis that 'satisfaction with the amount of time on-call work leaves for life (a composite score of satisfaction with amount of time for hobbies, friends, family, and self) will be significantly different between the different lengths of 'the longest consecutive period working on-call without sleep' (hypothesis 22) a one-way ANOVA was performed. 'Amount of time for life' was calculated by computing a composite score of the satisfaction with the amount of time on-call work leaves for hobbies, friends and family, and self. The correlations between the three indicators (r = 0.877; 0.905; and 0.920) were very high and as such allow for a strong composite variable to be created. Maximum amount of time working consecutively on-call was assessed through question five in the questionnaire: "What was the longest period of time you have worked on-call without sleeping?".

Table 6.10 below presents the results which show that the relationship between the length of the longest consecutive period working on-call without sleep and satisfaction with amount of time for life differ significantly.

Table 6.10 - Satisfaction with time for life (1 = Not satisfied at all, 5 = Very satisfied) and Longest period working on-call in hours

Factor		*Satisfaction with time for life* 8h to 12h	13h to 16h	17h to 20h	21h to 24h	More than 24h	ANOVA result
Longest period on-call without sleep	M	**3.54**	**2.98**	**2.45**	**2.37**	**2.37**	F(4,455) = 10.979***
	SD	1.11	1.19	1.14	1.11	1.24	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

Post hoc results using Tukey's test revealed that respondents who have not worked more than 16h when on-call are significantly more satisfied with the time on-call leaves them for their life when compared to those who have worked 17h or more. It seems there is a cut-off point at around 16h of work for satisfaction with the amount of time on-call work leaves respondents to live their life. Figure 6.8 below presents a summary of these results.

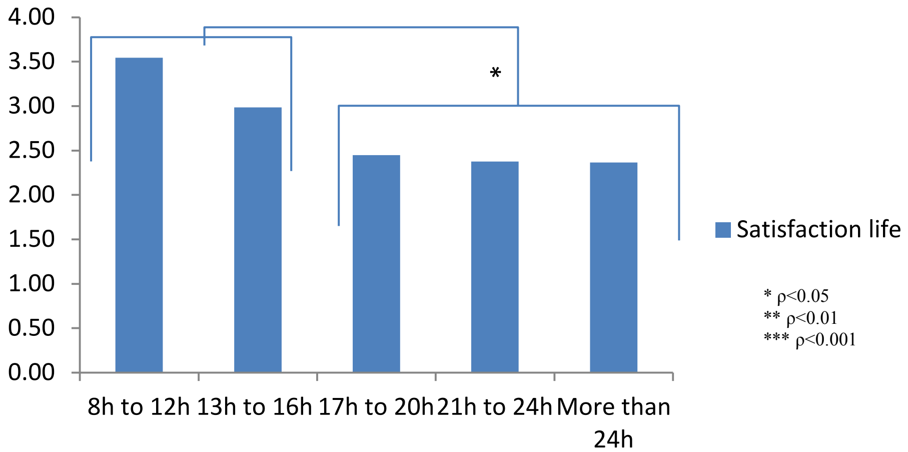


Figure 6.8 - Post-hoc tests for satisfaction with life per maximum amount of hours worked consecutively when on-call

ANOVAS were conducted to test the hypotheses that anxiety (as the composite score described above) and impact on well-being (as a composite score) when on-call will be significantly different when 'being required to work on-call when on leave' or not, and when 'being on a rostered off day' or not (hypothesis 23, hypothesis 24, hypothesis 25, and hypothesis 26). The well-being score was computed by averaging the well-being indicators (fatigue, stress, general well-being, family life, social life) when on-call (1 = no impact, 5 = very large impact) as all are heavily correlated (0.551 >= r >= 0.767).

Four one-way ANOVAs were conducted to assess these hypotheses. The results are presented below in Table 6.11 and solely support hypothesis 26 that states impact on well-being (as a composite score) when on-call will be significantly different when being required to work on a rostered off day or not.

Table 6.11 - Anxiety and Well-being when required to work on-call when on annual leave or rostered day off

		Required to work on-call when on leave		
Factor		**Yes**	**No**	**ANOVA result**
Anxiety	M	**3.01**	**2.96**	F(1,477) = 0.448
	SD	1.19	1.15	
Well-being	M	**3.45**	**3.30**	F(1,477) = 1.802
	SD	0.97	0.99	

		Required to work on-call on a rostered day off		
Factor		**Yes**	**No**	**ANOVA result**
Anxiety	M	**3.04**	**2.96**	F(1,477) = 0.195
	SD	1.17	1.18	
Well-being	M	**3.45**	**3.01**	F(1,477) = 6.283**
	SD	0.98	1.07	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

Satisfaction with on-call arrangements was hypothesised to be affected by all indicators of satisfaction (hypothesis 27, hypothesis 28, hypothesis 29). A positive correlation was found for the amount of time on-call work leaves for hobbies (r = 0.599), for family and social life (r = 0.598), and for self (r = 0.602). To assess if one, or all, could predict satisfaction with on-call work a multiple linear regression was performed.

Results are presented below in Table 6.12 and indicate that both satisfaction with time for hobbies and for family and social life have a positive relationship with satisfaction with on-call work. This means that the higher the satisfaction with time for hobbies and family and social life the higher the satisfaction with on-call work.

Table 6.12 - Satisfaction with on-call work

Satisfaction with on-call work		
Factor	**Beta**	**t-test**
Hobbies	**0.278**	t(456) = 3.100**
Family and social	**0.237**	t(456) = 2.408**
Self	**0.126**	t(456) = 1.135
R^2	0.383	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To assess if quality of sleep is significantly different between the different age groups for each of the on-call scenarios (not on-call, receiving callouts, and being on stand-by) predicted by hypothesis 30, hypothesis 31, and hypothesis 31, three one-way ANOVAs were performed. The analysis found no statistically significant differences between age and quality of sleep for any of the on-call scenarios. Table 6.13 below presents these results.

Table 6.13 - Quality of sleep per age group when not on-call, on stand-by, and being called-out

Factor		**Quality of sleep when not on-call per age group**					**ANOVA**
		Under 25	**25 to 34**	**35 to 44**	**45 to 56**	**Over 56**	
Not on-call	M	**3.83**	**4.13**	**4.09**	**4.17**	**4.09**	F(4,474) = 1.193
	SD	1.17	0.84	0.84	0.85	0.89	
		Quality of sleep when on stand-by per age group					
Stand-by	M	**3.00**	**3.35**	**3.35**	**3.47**	**3.57**	F(4,474) = 0.364
	SD	0.89	0.99	1.09	1.12	1.24	
		Quality of sleep when called-out per age group					
Called-out	M	**2.00**	**2.24**	**1.91**	**2.05**	**2.20**	F(4,474) = 1.406
	SD	0.89	1.23	1.00	1.04	1.05	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

6.5.8.3 Callouts and Fatigue, Stress, and Performance (hypothesis 45 to hypothesis 52)

It is predicted that the perceptions of fatigue, stress, and performance will be correlated to ‘number of callouts’ and the ‘percentage of callouts when already asleep’ (hypothesis 45, hypothesis 46, hypothesis 47,hypothesis 48, hypothesis 49, hypothesis 50, hypothesis 51, and hypothesis 52). To test these, a multivariate analysis of variance (MANOVA) was initially planned. In this situation with two callout factors (amount of callouts and percentage of calls after asleep) and several on-call outcomes (fatigue, stress, performance, and sleep quality score) it is recommended that an n-way MANOVA is used instead of multiple ANOVAS, as it protects against the Type 1 error from multiple tests, as would be the case when running several ANOVAS on the same dependent variables (Tabachnick & Fidell, 2007).

Performance scores were calculated by averaging all performance indicators (decision making ability, attention, alertness, speed of work, quality of work) from each on-call scenario (attending to site or providing telephone advice). To test the effect between the number and timing of callouts on fatigue, sleep and performance, both when solely providing telephone consultations and when attending site, a MANOVA was planned. The positive high correlation ($0.501 \le r \le 0.803$) between the dependent variables (on-call outcomes) in the test i.e., fatigue and stress when on-call, and performance scores, however, did not support the use of a MANOVA as it recommended to use MANOVAs only when the correlation between the dependent variables in the test is highly negative (about -0.6), or possibly when the correlation is moderate. When in the presence of positive correlation a MANOVA is less attractive and alternative tests should be used (Tabachnick & Fidell, 2007; Woodward, Bonnett, & Brecht, 1990).

It was, therefore, decided to run one-way ANOVAS for each on-call outcome (perceived fatigue, stress, and performance).

Results regarding the effect of the number and percentage of callouts on fatigue identified an effect on fatigue from the number of callouts and the percentage of these that occur after having gone to sleep. These results and those of Tukey’s post hoc tests are described below in Figure 6.9 and Figure 6.10.

Table 6.14 - Fatigue when on-call with number and percentage of callouts

Factor		Fatigue when on-call: 1-2 calls	3-4 calls	5-6 calls	7-8 calls	9-10 calls	> 10 calls	ANOVA
Number of calls	M	**2.96**	**3.17**	**3.41**	**3.79**	**3.85**	**3.82**	F(5, 469) = 9.949***
	SD	0.10	0.09	0.11	0.15	0.16	0.13	
			0% to 25%	**26% to 50%**	**51% to 75%**	**76% to 100%**		
Percentage of calls after asleep	M		**3.29**	**3.40**	**3.58**	**3.78**		F(3, 469) = 5.432*
	SD		0.10	0.10	0.09	0.10		

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

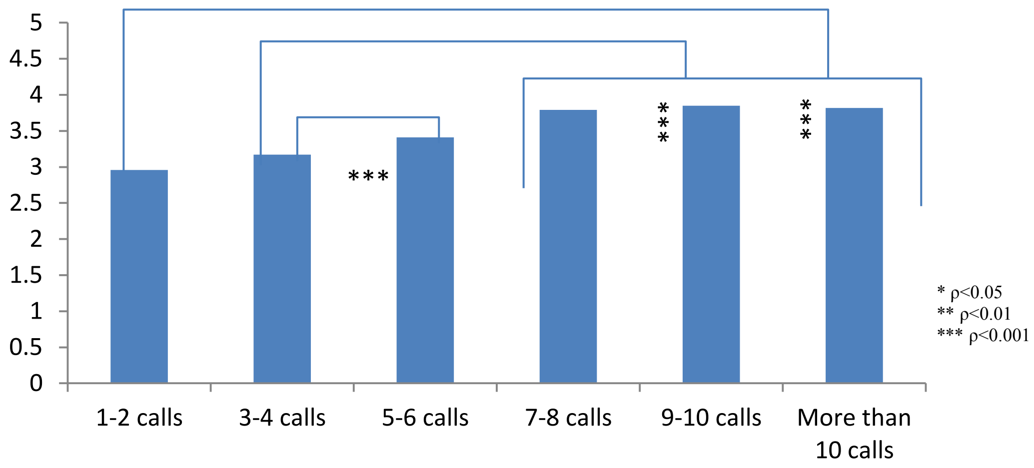


Figure 6.9 - Post Hoc tests between number of callouts and fatigue (1 = No impact, 5 = very large impact)

These results indicate that it is more fatiguing to receive more than four callouts on average per week when compared to receiving four or less callouts, and it is more fatiguing to receive seven callouts plus than to receive four callouts or less on average. To receive five or six calls on average is more fatiguing than receiving one to two callouts but not more fatiguing than receiving three to four calls, or any larger amount of calls. These results support hypothesis 45.

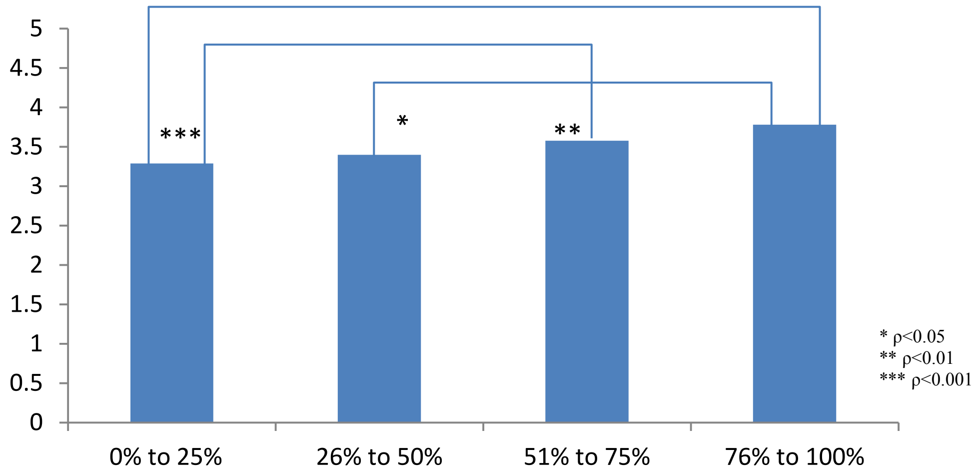


Figure 6.10 - Post Hoc tests between percentage of callouts when asleep and fatigue (1 = No impact, 5 = very large impact)

These results indicate that it is more fatiguing to receive 51% or more callouts when already asleep when compared to receiving 50% or less callouts when asleep. These results support hypothesis 46.

Results regarding the impact of the number of callouts on stress did not identify an effect for percentage of callouts that occur after having gone to sleep. An effect was, however, identified for the number of callouts. These results and those of Tukey's post hoc tests are described below in Table 6.15, and Figure 6.11. Empty cells represent non-significant values.

Table 6.15 - Stress when on-call per number and percentage of callouts

		Stress when on-call						
Factor		**1-2 calls**	**3-4 calls**	**5-6 calls**	**7-8 calls**	**9-10 calls**	**> 10 calls**	**ANOVA**
Number of calls	M	**2.96**	**3.16**	**3.40**	**3.71**	**3.55**	**3.82**	F(5,469) = 6.034***
	SD	0.12	0.10	0.12	0.17	0.18	0.14	
			0% to 25%	**26% to 50%**	**51% to 75%**	**76% to 100 %**		
Percentage of calls after asleep	M		**3.28**	**3.31**	**3.45**	**3.69**		F(3,469) = 2.664
	SD		0.12	0.12	0.10	0.11		

* ρ<0.05

** ρ<0.01

*** ρ<0.001

These results indicate that perceived stress when on-call is solely affected by the number of callouts received regardless of being asleep or not. These results support hypothesis 47 but not hypothesis 48.

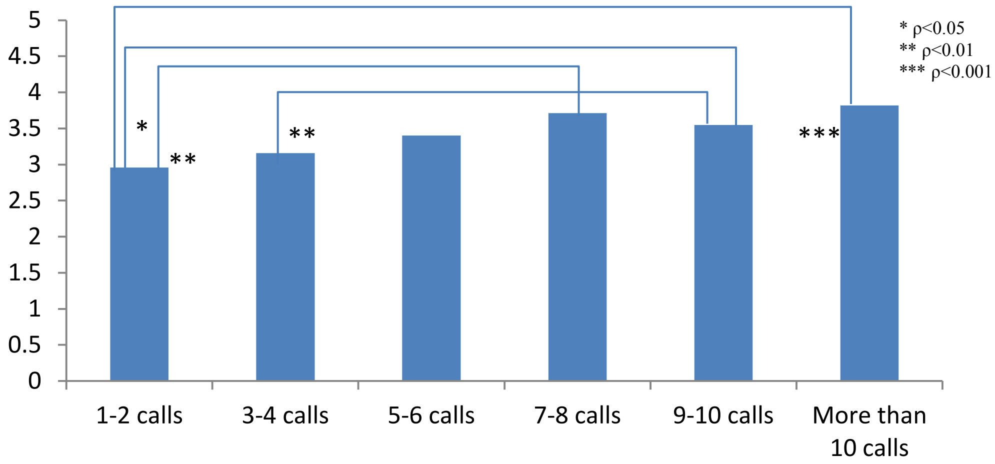


Figure 6.11 - Post Hoc tests between number of callouts and stress (1 = No impact, 5 = very large impact)

The results reveal that stress when receiving one to two callouts is lower than when receiving more than 10 callouts and that stress when receiving one to four callouts is lower than when receiving seven to ten callouts. In sum, it appears that receiving four callouts or less is not as stressful as receiving seven callouts or more.

Results regarding the impact of the number of callouts on performance when attending site did not identify an effect for percentage of callouts that occur after having gone to sleep. An effect was, however, identified for number of callouts. Table 6.16 below presents these results.

Table 6.16 - Performance when attending site with number and percentage of calls and

Factor		1-2 calls	3-4 calls	5-6 calls	7-8 calls	9-10 calls	> 10 calls	ANOVA
		Performance when on-call and attending site						
Number of calls	M	**2.30**	**2.29**	**2.61**	**2.83**	**2.74**	**2.80**	F(5,469) = 4.283 **
	SD	0.11	0.09	0.11	0.16	0.17	0.13	
			0% to 25%	**26% to 50%**	**51% to 75%**	**76% to 100%**		
Percentage of calls after asleep	M		**2.57**	**2.62**	**2.59**	**2.61**		F(3,469) = 0.052
	SD		0.11	0.11	0.09	0.10		

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

These results indicate that performance when attending site is solely affected by the number of callouts received regardless of being asleep or not. These results thus support hypothesis 49 but not hypothesis 50.

To identify the differences between the impact of the different number of callouts post hoc tested were performed with Tukey post hoc tests revealing that when required to attend site respondents feel their performance is significantly more affected when they receive seven callouts or more when compared to receiving four callouts or less as shown in Figure 6.12.

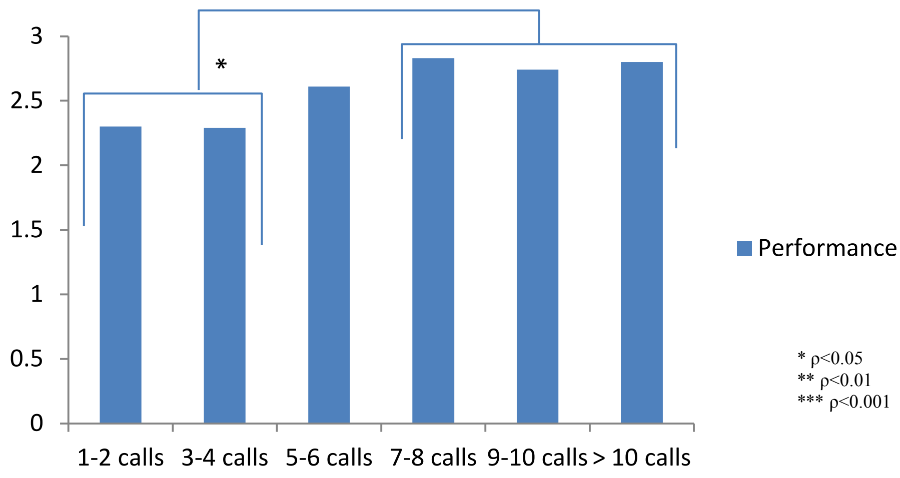


Figure 6.12 - Post-hoc number of calls on performance

Similarly, results regarding the impact of the number of callouts on performance when providing advice over the telephone did not identify an effect for percentage of callouts that occur after having gone to sleep. An effect was, however, identified for the number of callouts. Table 6.17 below presents these results.

Table 6.17 - Performance when on-call and providing advice with number and percentage of calls

Performance when on-call and providing advice

Factor		1-2 calls	3-4 calls	5-6 calls	7-8 calls	9-10 calls	> 10 calls	ANOVA
Number of calls	M	**2.36**	**2.49**	**2.59**	**2.80**	**2.77**	**2.91**	F(5,469) = 3.142*
	SD	0.10	0.09	0.11	0.15	0.16	0.13	
			0% to 25%	**26% to 50%**	**51% to 75%**	**76% to 100 %**		
Percentage of calls after asleep	M		**2.59**	**2.57**	**2.69**	**2.77**		F(3,469) = 0.821
	SD		0.11	0.10	0.09	0.10		

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

These results also indicate that performance when providing telephone advice is only perceived to be affected by the number of calls. These results support hypothesis 51 but not hypothesis 52.

To identify the differences between the impact caused by the different number of callouts Tukey post hoc tests were performed. The tests, as shown below in Figure 6.13, reveal that performance when providing advice on the telephone is perceived as being more affected when receiving more than 10 callouts from when receiving four calls or less.

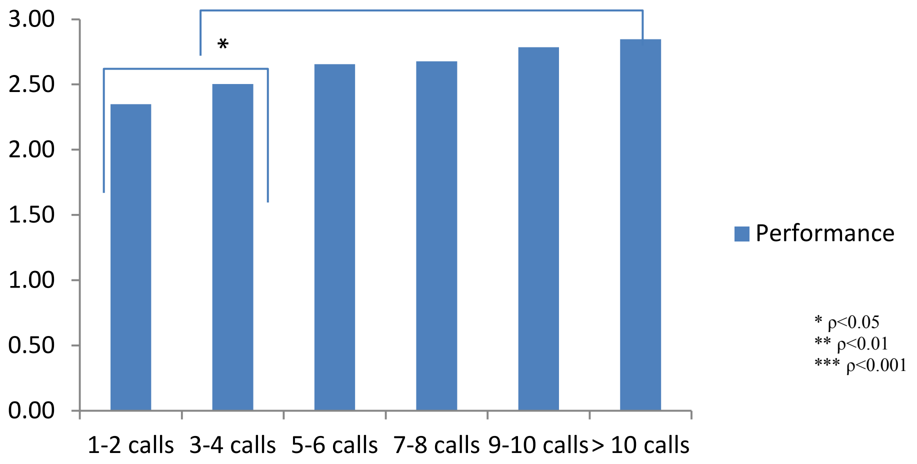


Figure 6.13 - Post-hoc number of callouts on performance when providing advice over the telephone

4.5.8.4 Callouts and Quality of sleep (hypothesis 53 and hypothesis 54)

Two one-way ANOVAs were performed to test the hypotheses that quality of sleep will be statistically different both between the number of callouts and the percentage of calls that lead to being awake for more than 30 minutes after receiving a callout (hypothesis 53 and hypothesis 54).

Both hypotheses were supported with results indicating that quality of sleep is statistically different both between the number of callouts received and the percentage of callouts that lead to being awake for more than 30 minutes. Results are presented below in Table 6.18.

Table 6.18 - Sleep quality (1 =Extremely low, 5 =extremely high) when on-call with number of calls and calls that impede sleep for more than 30min

				Sleep quality when on-call				
Factor		**1-2 calls**	**3-4 calls**	**5-6 calls**	**7-8 calls**	**9-10 calls**	**more than 10 calls**	**ANOVA**
Number of calls	M	**2.48**	**2.28**	**1.96**	**1.54**	**1.68**	**1.58**	F(5,473) = 11,847***
	SD	1.11	1.09	1.03	0.91	0.69	0.77	
			0% to 25%	**26% to 50%**	**51% to 75%**	**76% to 100%**		
Percentage of calls awake >30min	M		**3.09**	**2.30**	**1.83**	**1.64**		F(5,473) = 54.475***
	SD		1.09	0.95	0.76	0.86		

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To identify the differences between the impact of the different number of callouts post hoc tests were performed. Tukey post hoc tests revealed that receiving four callouts or less has a smaller impact on the quality of sleep score than receiving seven or more callouts. Receiving five to six callouts were also found to be more detrimental to sleep quality than receiving one to two callouts but less detrimental than receiving more than 10 callouts. Figure 6.14 shows these results.

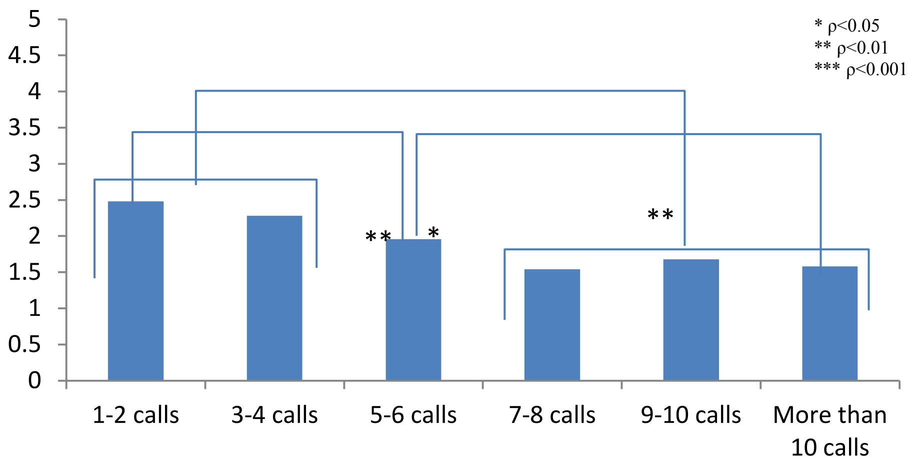


Figure 6.14 - Post Hoc tests between number of callouts when asleep and the sleep quality score (1 =Extremely low, 5 =extremely high)

Similarly, to assess the differences between the impact of different percentage of callouts that lead to being awake for 30 minutes or more Tukey post hoc tests were performed. The results reveal that the lower the percentage of callouts that lead to being awake for 30 minutes or more the better the quality of sleep. Figure 6.15 below presents a summary of these results.

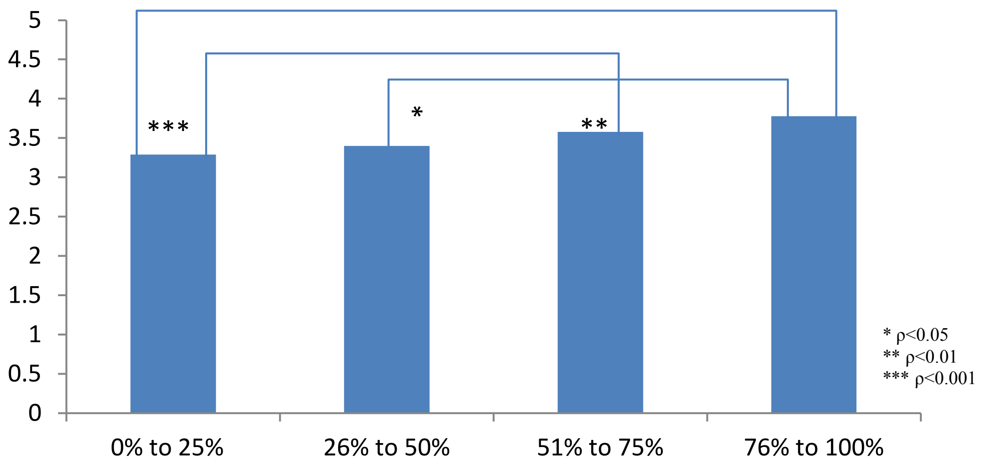


Figure 6.15 - Post Hoc tests between the percentage of callouts that prevent sleep for 30 min and quality of sleep (1 =Extremely low, 5 =extremely high)

4.5.8.5 Callouts and Well-being (hypothesis 55)

To test whether well-being (as a composite score of fatigue, stress, general well-being, satisfaction with amount of free time for social and family life) when on-call will be statistically different between the different percentage of calls that lead to being awake for more than 30 minutes after a callout (hypothesis 55) a one-way ANOVA was conducted. Results were found to support the hypothesis and are shown Table 6.19.

Table 6.19 – Well-being (1 =Extremely low, 5 =extremely high) with percentage of callouts that keep you awake for more than 30min

		Well-being when on-call				
		0% to 25%	**26% to 50%**	**51% to 75%**	**76% to 100%**	
Percentage of calls awake >30min	M	**2.78**	**3.25**	**3.44**	**3.69**	$F(3,474) = 20.074^{***}$
	SD	1.08	0.85	0.90	0.93	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

Tukey post hoc tests show that the higher the percentage of callouts that prevent sleep for at least 30 minutes, the more affected well-being is. Figure 6.16 below shows details of this.

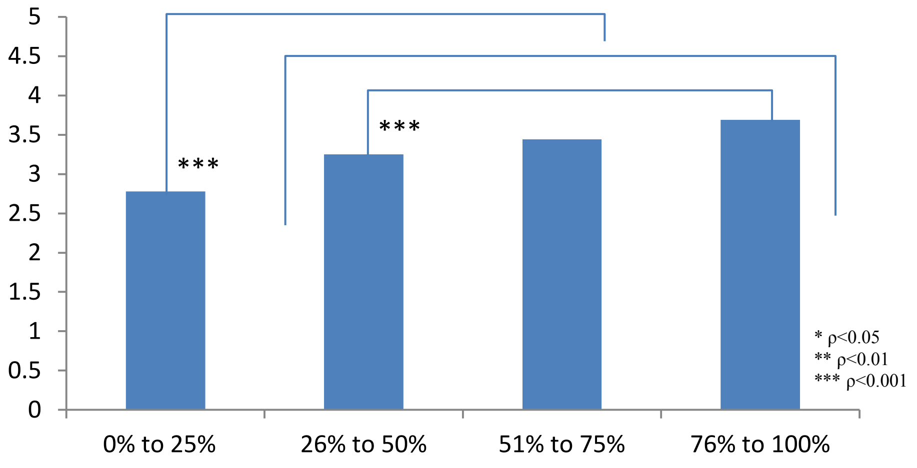


Figure 6.16 - Post Hoc tests of percentage of callouts that prevent sleep for 30 min and well-being score (1 = No impact, 5 = very large impact)

6.4.8.6 Anxiety and sleep quality, Well-being and sleep (hypothesis 56 to hypothesis 58)

To test the hypothesis that sleep quality when on stand-by will be affected by anxiety (as a composite score) (hypothesis 56) a linear regression was conducted.

The anxiety score is a composite factor constructed from the average scores of the three anxiety questions posed in the survey i.e. "how anxious do you feel regarding, a) expecting the phone to ring? b) not knowing when and if you will get a call? c) the call itself?)". The three factors had a high correlation (0.877 <= r <= 0.920). The response scale varies from "1 = not at all" to "5 = a lot".

The results are presented below in Table 6.20 and indicate that the lower the anxiety felt by respondents, the lower the impact on their sleep when on stand-by supporting the hypothesis.

Table 6.20 - Well-being (1 = no impact, 5 = very large impact) and anxiety ("1 = not at all" to "5 = a lot")

	Sleep quality	
Factor	**Beta**	**t-test**
Anxiety	**-0.471**	t(477) = -11.665***
R^2	0.120	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

A multiple linear regression analysis was performed to test the hypotheses that well-being (as a composite score) when on-call will be affected by sleep quality (hypothesis 57) and that well-being (as a composite score) when on-call will be affected by sleep quantity (hypothesis 58). Results support the hypotheses and are presented below in Table 6.21, revealing that the higher the quality and quantity of sleep the lower the impact felt on well-being.

Table 6.21 - Well-being (1 = no impact, 5 = very large impact) with sleep quantity and sleep quality (1 =Extremely low, 5 =extremely high).

Well-being when on-call work		
Factor	**Beta**	**t-test**
Sleep quality	**-0.572**	t(478) = - 13.770***
Sleep quantity	**-0.136**	t(478) = - 3.272***
R^2	0.428	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

6.6 Discussion

The results mainly support the findings of Study 1. Nonetheless, there were a number of hypotheses that were not verified. Table 6.22 shows a summary of the hypotheses tested and the outcomes of the tests which are then discussed in further detail.

Table 6.22 - Summary of hypothesis testing

Number	Hypothesis	Support (Y/N)	Test	Result
Hypothesis 1	on-call rosters will be organised in rosters	Y	-	97.1% of respondents have an on-call roster
Hypothesis 2	on-call work will be mandatory	Y	-	97.2 % of respondents are required to work on-call
Hypothesis 3	it will be possible to be rostered to work on-call whilst on annual leave	Y	-	79.3% of respondents stated it is possible to be on annual leave and still be rostered to work on-call
Hypothesis 4	it will be possible to be rostered to work on-call whilst on a rostered day off or on a rostered weekend off	Y	-	91% of respondents stated it is possible to be rostered on-call when also on a rostered day off or weekend
Hypothesis 5	increased pay will not be a reason to work on-call	Y	-	M = 1.64, SD = 1.17; 1 = Not a reason for me, 5 = Very much a reason for me
Hypothesis 6	uncertainty about when a callout will occur will be a cause of anxiety	Y	-	M = 3.25, SD = 1.36, 1 = not at all, 5 = a very large extent
Hypothesis 7	anticipating a callout will be a cause of anxiety	Y	-	M = 3.26, SD = 1.36, 1 = not at all, 5 = a very large extent
Hypothesis 8	fatigue as a well-being indicator will be significantly different when working on-call and not working on-call work	Y	$t(478) = 23.355, p<0.001$	All well-being indicators significantly worse when on-call compared to not being on-call
Hypothesis 9	Stress as a well-being indicator will be significantly different when working on-call and not working on-call work	Y	$t(478) = 20.292, p<0.001$	All well-being indicators significantly worse when on-call compared to not being on-call
Hypothesis 10	general well-being as a well-being indicator will be significantly different when working on-call and not working on-call work	Y	$t(478) = 21.545, p<0.001$	All well-being indicators significantly worse when on-call compared to not being on-call
Hypothesis 11	satisfaction with time for family life as a well-being indicator will be significantly different when working on-call and not working on-call work	Y	$t(478) = 23.816, p<0.001$	All well-being indicators significantly worse when on-call compared to not being on-call
Hypothesis 12	satisfaction with time for social life as a well-being indicator will be significantly	Y	$t(478) = 25.978, p<0.001$	All well-being indicators significantly worse when on-call compared to not being on-call

	different when working on-call and not working on-call work			
Hypothesis 13	satisfaction with on-call work will be significantly different from satisfaction with the job in general	Y	$t(478) = 11.465$, $p<0.001$	Satisfaction with on-call work significantly worse than satisfaction with job in general
Hypothesis 14	well-being (as a composite score of fatigue, stress, general well-being, satisfaction with amount of free time for social and family life) when working on-call will be significantly different between slow and fast rotating rosters (as defined by participants in Study 1)	N	$F(1,436) = 2.968$, ρ = n.s	No significant result found
Hypothesis 15	satisfaction with on-call work will be significantly different between slow and fast rotating rosters (as defined by participants in Study 1)	N	$F(1,436) = 1.037$, ρ = n.s	No significant result found
Hypothesis 16	sleep quantity when on stand-by will be affected by on-call experience (years working on-call)	N	$\beta = -0.019$, $t(477) = 32.914$, ρ = n.s	No significant result found
Hypothesis 17	satisfaction with amount of sleep when on stand-by will affected by on-call experience (years working on-call)	N	$\beta = 0.039$, $t(477) = 37.776$, ρ = n.s	No significant result found
Hypothesis 18	sleep quality when on stand-by will be affected by on-call experience (years working on-call)	N	$\beta = 0.037$, $t(477) = 35.697$, ρ = n.s	No significant result found
Hypothesis 19	restfulness after sleep when on stand-by will affected by on-call experience (years working on-call)	N	$\beta = 0.021$, $t(477) = 38.698$, ρ = n.s	No significant result found
Hypothesis 20	fatigue when on stand-by will be affected by on-call experience (years working on-call)	N	$\beta = -0.012$, $t(477) = 34.741$, ρ = n.s	No significant result found
Hypothesis 21	anxiety when on-call (as a composite score of anxiety regarding expecting the phone to ring, not knowing when and if you will get a call, and the call itself) will be will be affected by experience (measured through	N	$\beta = -0.050$, $t(477) = 32.914$, ρ = n.s	No significant result found

	number of years working on-call)			
Hypothesis 22	satisfaction with the amount of time on-call work leaves for life (a composite score of satisfaction with amount of time for hobbies, friends, family, and self) will be significantly different between the different lengths of 'the longest consecutive period working on-call without sleep'	Y	$F(4,455) = 10.979, p<0.001$	Respondents who have not worked more than 16h when on-call are significantly more satisfied with the time on-call leaves them for their life when compared to those who have worked more than 17h.
Hypothesis 23	anxiety (as a composite score) levels when on-call will be significantly different when 'being required to work on-call when on leave' or not	N	$F(1,477) = 0.448$, ρ = n.s	No significant result found
Hypothesis 24	anxiety (as a composite score) when on-call will be significantly different when being 'required to work when on a rostered off day' or not	N	$F(1,477) = 0.195$, ρ = n.s	No significant result found
Hypothesis 25	well-being (as a composite score of fatigue, stress, general well-being, satisfaction with amount of free time for social and family life) when on-call will be significantly different when 'being required to work on-call when on leave' or not	N	$F(1,477) = 1.802$, ρ = n.s	No significant result found
Hypothesis 26	well-being (as a composite score) when on-call will be significantly different when being required to work on a rostered off day or not	Y	$F(1,477) = 6.283, p<0.01$	Well being is significantly worse when required to work on-call on a rostered day off.
Hypothesis 27	satisfaction with on-call arrangements will be affected by the satisfaction with the amount of free time for hobbies	Y	$\beta = 0.278$, $t(456) = 3.100, p<0.01$	The higher the satisfaction with time for hobbies the higher the satisfaction with on-call work.
Hypothesis 28	satisfaction with on-call arrangements will be affected by the satisfaction with the amount of free time for family and social life	Y	$\beta = 0.237$, $t(456) = 2.408, p<0.01$	The higher the satisfaction with time for family and social life the higher the satisfaction with on-call work.
Hypothesis 29	satisfaction with on-call arrangements will be affected by the satisfaction with the	N	$\beta = 0.126$, $t(456) = 1.135$, ρ = n.s	No significant result found

	amount of free time for self			
Hypothesis 30	quality of sleep when not on-call will be significantly different between the different age	N	F(4,474) = 1.193, ρ = n.s	No significant result found
Hypothesis 31	quality of sleep when on stand-by will be significantly different between the different age groups	N	F(4,474) = 0.364, ρ = n.s	No significant result found
Hypothesis 32	quality of sleep when receiving callouts will be correlated with age groups	N	F(4,474) = 1.406, ρ = n.s	No significant result found
Hypothesis 33	sleep quantity will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call	Y	F(1.686, 791.542) = 1424.005, p<0.001	All three scenarios were significantly different from each other with ρ < 0.001 with receiving callouts with the lower sleep quantity followed by stand-by.
Hypothesis 34	satisfaction with the amount of sleep will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call	Y	F(1.835, 877.328) = 964.492, p<0.001	All three scenarios were significantly different from each other with ρ < 0.001 with receiving callouts with the lower satisfaction followed by stand-by.
Hypothesis 35	sleep quality will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call	Y	F(1.824, 871.727) = 933.600, p<0.001	All three scenarios were significantly different from each other with ρ < 0.001 with receiving callouts with the lower sleep quality followed by stand-by.
Hypothesis 36	restfulness after sleep will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call	Y	F(1.828, 873.759) = 928.821, p<0.001	All three scenarios were significantly different from each other with ρ < 0.001 with receiving callouts with the lower restfulness followed by stand-by.
Hypothesis 37	fatigue after sleep will be significantly different when working on-call and receiving callouts, working on-call without receiving callouts, and not working on-call	Y	F(1.318, 628.993) = 67.545, p<0.001	All three scenarios were significantly different from each other with ρ < 0.001 with receiving callouts with the higher fatigue followed by stand-by.

Hypothesis 38	decision making as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation	Y	t(478) = 3.851, p<0.001	Decision making is, on average, more affected when responding to callouts over the telephone than when required to attend site to deal with the fault.
Hypothesis 39	attention as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation	Y	t(478) = 3.217, p<0.001	Attention is, on average, more affected when responding to callouts over the telephone than when required to attend site to deal with the fault.
Hypothesis 40	alertness as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation	Y	t(478) = 2.178, p<0.01	Alertness is, on average, more affected when responding to callouts over the telephone than when required to attend site to deal with the fault.
Hypothesis 41	speed of work as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation	N	t(478) = 0.114, ρ = n.s	No significant result found
Hypothesis 42	quality of work as a performance indicator will be significantly different between being called-out and required to attend site and solely providing a telephone consultation	Y	t(478) = 2.150, p<0.01	Quality of work is, on average, more affected when responding to callouts over the telephone than when required to attend site to deal with the fault.
Hypothesis 43	mood will be significantly different between being called-out and required to attend site and solely providing a telephone consultation	Y	t(478) = 3.707, p<0.001	Mood when required to attend faults is significantly worse than when solely required to provide advice over the telephone
Hypothesis 44	motivation will be significantly different between being called-out and required to attend site and solely providing a telephone consultation	N	t(478) = 0.974, ρ = n.s	No significant result found
Hypothesis 45	fatigue when on-call will be statistically different between different number of	Y	F(5, 454) = 8.050, p<0.001	It is more fatiguing to receive more than four callouts on average per week when compared

	callouts			to receiving four or less callouts
Hypothesis 46	fatigue when on-call will be statistically different between different percentage of callouts after going to sleep	Y	F(3, 454) = 3.500, p<0.5	It is more fatiguing to receive 51% or more callouts when already asleep when compared to receiving 50% or less.
Hypothesis 47	stress when on-call will be statistically different between different number of callouts	Y	F(5,454) = 5.187, p<0.001	Stress when receiving four callouts or less is lower than when receiving seven callouts or more.
Hypothesis 48	stress will be statistically different between different percentage of callouts after going to sleep	N	F(3,454) = 1.725, ρ = n.s	No significant result found
Hypothesis 49	performance when on-call and required to attend site will be statistically different between different number of callouts	Y	F(5,454) = 3.850, p<0.01	When required to attend site performance is significantly more affected when receiving seven callouts or more when compared to receiving four callouts or less
Hypothesis 50	performance when on –call and required to attend site will be statistically different between different percentage of callouts after going to sleep	N	F(3,454) = 0.002, ρ = n.s	No significant result found
Hypothesis 51	performance when on-call and providing advice over the telephone will be statistically different between different number of callouts	Y	F(5,454) = 2.295, p<0.5	When providing advice on the telephone performance is perceived as being significantly more affected when receiving more than 10 callouts from when receiving four calls or less.
Hypothesis 52	performance when on-call and providing advice over the telephone will be statistically different between different percentage of callouts after going to sleep	N	F(3,454) = 0.778, ρ = n.s	No significant result found
Hypothesis 53	quality of sleep when on-call will be statistically different between different number of callouts	Y	F(5,473) = 11,847, p<0.001	Sleep quality is significantly better when receiving four callouts or less than receiving 5 or more callouts
Hypothesis 54	quality of sleep when on-call will be statistically different between the different percentage of calls that lead to being awake for more than 30 minutes after receiving a	Y	F(5,473) = 54.475, p<0.001	The lower the percentage of callouts that lead to being awake for 30 minutes or more the better the quality of sleep

	callout			
Hypothesis 55	well-being (as a composite score of fatigue, stress, general well-being, satisfaction with amount of free time for social and family life) when on-call will be statistically different between the different percentage of calls that lead to being awake for more than 30 minutes after a callout	Y	F(3,474) = 20.074, p<0.001	The higher the percentage of callouts that prevent sleep for at least 30 minutes the more affected well-being is
Hypothesis 56	sleep quality when on stand-by will be affected by anxiety (as a composite score)	Y	β = -0.471, t(477) = -11.665, p<0.001	The higher the anxiety felt by respondents, the higher the impact on their sleep quality
Hypothesis 57	well-being (as a composite score) when on-call will be affected by sleep quality	Y	β = -0572, t(478) = 13.770, p<0.001	The higher the sleep quality the lower the impact on well-being
Hypothesis 58	well-being (as a composite score) when on-call will be affected by sleep quantity	Y	β = -0136, t(478) = 3.272, p<0.001	The higher the sleep quantity the lower the impact on well-being

6.6.1 On-call arrangements (hypothesis 1 to hypothesis 13)

The survey results, as expected, demonstrate that rosters are the most common way used to prepare on-call work and, that within this arrangement, weekly long rosters are the preferred method. Most of the rosters identified are slow rotating rosters, although there are still around one quarter of respondents who work under fast rotating rosters. The spikes in the number of days working on-call on seven, 14, 21, and 28 days are explained by the way on-call work is managed in the event of annual leave, sickness, or any other factors that might cause a worker to be absent from work. When one of these events occurs the on-call period is typically covered by one of the other on-call workers. This multiplies the on-call period from one week to two or more.

It was also verified that on-call work is mandatory for the great majority of respondents and, as such, the main reason to work on-call is because it is a requirement of the respondent's position in the company. Furthermore, results also show that, as predicted, the majority of on-call rosters are not aligned with other working hours arrangements in place at the company. As a result on-call workers can be required to work on-call when on a rostered day off, a rostered weekend off, or when on annual leave. In these instances it is usually the worker himself that must find a solution to this problem, swapping the shift with a co-worker. These findings further support the findings of Study 1 that on-call managerial staff are responsible for managing their own working hours. As a result increased pay was not found to be a reason to work on-call.

These results together with the need to maintain *normal working hours* also offer some insight to why respondents feel on-call has a large impact on them in regards to all well-being indicators assessed (fatigue, stress, general well-being, time for family, time for social activities) when compared to not being on-call, and why they are satisfied with their jobs but not with on-call work.

Anxiety when on-call was also found to be increased due to the anticipation of a callout and the uncertainty of when a callout will occur. Uncertainty as a cause of anxiety when on-call had already been hinted at by other on-call research with ship engineers (Torsvall & Akerstedt, 1988).

6.6.2 Implementing factors (hypothesis 14 to hypothesis 32)

No differences were found with regards to both well-being and satisfaction with on-call work between respondents that operate under slow rotating rosters and those that operate under fast rotating rosters. This is contrary to the statements of a number of interviewees in Study 1 which stated that on-call frequency was a great influence both to well-being and the satisfaction felt with on-call work. On-call research has yes to explore the impacts of different rostering arrangements on the well-being of workers but shiftwork research has identified shift arrangements as one of the key deleterious factors in shiftwork (e.g. Barnes-farrell et al., 2008; Costa, 1997; Mitchell & Williamson, 2000). For example, some research has identified that shiftwork schedules have a negative impact on relationship stability, especially for couples with children and that shiftworkers have an increased risk of divorce and of their children to suffer from anxiety and behavioural problems (e.g. Bianchi, 2011; Presser, 2000).

The lack of findings in this thesis could be due to factors not considered in this analysis such as personality, or the fact that individuals whose well-being and satisfaction with such rosters is so low, have moved on to different roles. It could also be due to limitations in the research protocol, as the data collected reflects the recollection of perceived differences and, as a result, is vulnerable to recollection bias. This is a general limitation of the study. The way fast and slow rosters were coded may not be the best way to define fast and slow rotating rosters, even though the coding was based on previously collected data from Study 1. Another possibility is that the high flexibility present in the on-call scheduling system with the ability to swap shifts freely allows on-call staff to maintain reasonable levels of well-being and satisfaction with faster rotating rosters.

Given that respondents manage their own working hours and that on-call work itself is unregulated, a large number of respondents reported having worked on-call for longer than 12 hours and around 70% have previously worked periods longer than 17 consecutive hours. This results in respondents who work more than 17 hours consecutively being significantly less satisfied with on-call work than those that work 16 hours or less. This is in accordance with the findings of sleep research where extended wakefulness up to around 16 hours leads to both increases sleepiness and decreased performance (Dorrian et al., 2011; Van Dongen, Maislin, et al., 2003).

It would appear that it may also lead to reduced satisfaction, at least regarding on-call work.

Predictably, satisfaction with on-call work was found to vary between being on-call and receiving callouts, being on stand-by, and not being on-call, with satisfaction being at its lowest when receiving callouts followed by being on stand-by. Similarly, satisfaction was found to be associated with the amount of free time for hobbies, family and social life, and for the self. These results are in accordance with shiftwork research that has found that working long shifts has a general deleterious effect on well-being and satisfaction with work. (e.g, Bendak, 2003; Pilcher, Lambert, & Huffcutt, 2000; Spencer et al., 2006). On-call specific research has also found similar results where proximal on-call practitioners working more than 40h per week on-call were less satisfied and had higher turnover intentions that those that worked less than 40h (Heponiemi et al., 2008).

Contrary to the findings of Study 1 no effects were found for experience with regards to anxiety or sleep indicators. Anxiety, sleep quantity, satisfaction with amount of sleep, sleep quality, restfulness after sleep, and fatigue were all found not to be associated with experience. It is possible that the way experience was assessed (years working on-call) did not actually reflect experience or it may be that experience is not correlated with anxiety or sleep indicators. Shiftwork research has only identified an effect from experience on performance and even this has been associated with other factors: “lower workload during the night, lack of monotony, and to the processes being relatively inert and forgiving to minor operator errors.” (Gillberg et al., 2003, p.101).

In the same line no relationship was identified between age and sleep quality. Although there is evidence that older shiftworkers can find it harder to work shifts (e.g. Costa & Di Milia, 2008; Mikko Harma, 1996; Pires et al., 2009), with sleep quality being one of the factors identified, these results were not replicated in this thesis. Sleep, through the homeostatic sleep process, associated with circadian influence, is a very strong sleep driving process. It may be that, if the number of calls that disturb sleep are quite low, the sleep drive overcomes the effects of age on sleep quality (Kong, 2008; M. R. Smith et al., 2008). It may also be that these results simply reflect the limitations of this study where recollection bias may be distorting the results.

When assessing anxiety, it was surprising that the possibility of having to work on-call when on leave and when on a rostered day off did not lead to higher levels of anxiety as stated by interviewees in Study 1. It could simply be that these have become so common place that interviewees are, in a way, used to them so much so that they to not cause them anxiety anymore.

Similarly, well-being when being required to work on-call when on annual leave was not found to be affected. However, well-being was found to be affected when required to work on-call when on a rostered day off. These are surprising results as it would be expected that both events would cause well-being to be decreased. It may be that respondents have found a way to reduce the impact of on-call work when on leave but not when on a rostered day off.

6.6.3 On-call scenarios and sleep (hypothesis 33 to hypothesis 37)

As predicted all five sleep indicators assessed (sleep quantity, sleep quality, the restorative effect of the sleep period, how rested, and how fatigued respondents feel after sleep) were found to be statistically different between each of the three on-call scenarios assessed. Receiving callouts was identified as the most damaging scenario followed by being on stand-by. These results are aligned with both findings from Study 1 and from literature. Sleep research has clearly identified a negative relationship between sleep disruption and sleep fragmentation and sleep indicators (e.g. Ekstedt et al., 2009; Lim et al., 2012; Martin et al., 1996; Stepanski et al., 1984; Stepanski, 2002), and interviewees stated even the reception of one call could cause great unrest. Furthermore, sleep research shows that sleep indicators should be expected to be more affected when receiving calls due to repetitive sleep deprivation through repeated disruption. Sleep recovery research has also shown that only consolidated sleep allows for restoration which is exactly the type of sleep that on-call work interrupts (e.g. Belenky et al., 2003; Dawson & Mcculloch, 2005). As described by interviewees, being on stand-by alone affects sleep indicators as it is expected that workers stay up later in anticipation of a callout. Also, as shown by other on-call and shiftwork research anxiety has a detrimental effect on sleep (e.g. Åkerstedt, 2006b; Asltoghiri & Ghodsi, 2011; Ekstedt et al., 2009; Torsvall & Akerstedt, 1988).

6.6.4 On-call events (hypothesis 38 to hypothesis 58)

It was somewhat surprising that respondents did not feel a strong impact in their performance when being called-out. More surprising was the perception that performance is more deteriorated when providing a telephone consultation than when attending site. This was true for four of the five performance indicators assessed (decision making, attention, alertness, and quality of work) with only speed of work not being statistically different between the two call-out scenarios.

A possible explanation for this could be that the act of leaving the house helps workers to overcome inertia by being required to travel (e.g. (Miccoli et al., 2008; Wertz et al., 2006), thus giving respondents the impression of being less affected. It could also be that these findings reflect a weakness of the research protocol as it relies on the recollected perceptions of situations that do not occur frequently. Managers are not required to attend site frequently and as a result, might be unable to recall these situations with accuracy.

Less surprising results were found with regards for mood which was found to be statistically more deteriorated when required to attend faults than when solely providing advice over the telephone. Although on-call research assessing mood has found that on-call work is associated with declining mood (Saxena & George, 2005; Wesnes et al., 1997), this work has not assessed different call-out scenarios. Sleep disruption research has also found a clear relationship between sleep fragmentation and reduced mood (e.g. Bonnet, 1985; Bonnet & Arand, 2003; Stepanski, Lamphere, Badia, Zorick, & Roth, 1984), which gives some justification to why on-call research has been found to be associated with mood decrements. Shiftwork research has also found that fatigue itself is a cause of decreased mood and so is reduced sleep quality (Edéll-Gustafsson, 2002). More than this, extended wakefulness beyond 16h, has also been shown to lead to mood deterioration (Cao et al., 2008). Regardless of the lack of research comparing on-call scenarios, or of similar research, it must be expected that being required to physically exit the house and travel to a fault location would lead to decreased mood as it increases the length of the disruption and requires more actions from the worker. This also disrupts sleep more than a potentially 'short' telephone call.

Contrary to mood, motivation was not found to vary between being required to attend site or to provide telephone advice. Although no other on-call research has compared the effects of motivation between on-call scenarios, sleep research has identified that motivation appears to maintain performance at pre-sleep deprived levels if wakefulness does not exceed 24 hours or if sleep is not restricted to less than 50% of the normal daily amount (Dinges & Kribbs, 1991). These results go some way to justify the lack of significant results found in this thesis which contradicts how some interviewees feel regarding these on-call scenarios.

As predicted fatigue levels when receiving call-outs were found to vary in accordance to both number of call-outs and percentage of call-outs when already asleep. This is in accordance with Study 1, where interviewees stated that after receiving a call-out it is hard to relax and go back to sleep due to worrying about decisions made. Sleep research has clearly identified that sleep fragmentation leads to both to low sleep quality and increased fatigue (e.g. Bonnet & Arand, 2003; Levine, Roehrs, Stepanski, Zorick, & Roth, 1987; Stepanski, 2002). More than this, sleep research has also identified that disruption in the deeper stages of sleep is more damaging to both the quality of sleep and the ability to fall back asleep (e.g. Kerkhof & Van Dongen, 2010; Pinel, 1992), which can also be a factor of influence here. Another possible explanation comes from sleep inertia research where it has been identified that upon conquering sleep inertia it becomes more difficult to fall back asleep (e.g. Balkin & Badia, 1988; Miccoli et al., 2008; Wertz et al., 2006). It is possible that after a the reception of a small percentage of calls, or calls that disrupt the deeper stages of sleep the ability to fall back asleep is more compromised resulting in reduced sleep quantity and quality which in turn leads to increased fatigue.

Surprisingly, similar results were found neither for stress nor performance either when attending site or providing advice over the telephone. Both stated to be the case by interviewees in Study 1. Both stress and performance were only found to be affected by the number of callouts.

On-call research has linked stress, and anxiety in particular, to the on-call experience itself and to the anticipation of a callout (Imbernon et al., 1993; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988). If stress is seen as an imbalance between demands and our ability to meet them resulting in a perturbation of the psycho-physical equilibrium where stress arises from the inability to cope with this imbalance (Costa, 1995) then it could be that the lack of significant results indicates that the contents or the requirements of the callouts are not exceptional but common. It could also be that a higher number of calls indicates an issue or fault with greater implications or more troublesome to solve thus justifying the relationship found between higher number of callouts and stress. Other possibilities arise from sleep research which has identified that reduced sleep quantity (in this case caused by a high number of callouts) is a cause of stress (e.g. Edéll-Gustafsson et al., 2002; Pilcher et al., 1997). However, if this was the case a significant effect with percentage of callouts when already asleep was expected also. Furthermore, the high correlation ($r = 0.767$) found between fatigue and stress indicates that there is a good chance that those respondents that feel more fatigued are also those that feel more stressed.

Similarly the lack of a significant effect on performance by percentage of callouts when already asleep is also surprising as sleep research has clearly shown that the early hours of the morning are the times when performance is at its lowest, and sleepiness and the risk of accidents are at their maximum. This has been shown to be related both to the sleep drive and the sleep-wake circadian rhythm (e.g. McGuffog, Turner, & Stone, 2004; Spencer et al., 2006). With regards to the significant result found for number of callouts, performance has been found to be deteriorated both by on-call work (Saxena & George, 2005; Wesnes et al., 1997) and shiftwork (Eriksen & Kecklund, 2007; Knauth, 1996; Morrow & Crum, 2004). Sleep research has found that sleep debt has a detrimental impact on a large number of performance related factors (e.g. Caldwell, Caldwell, & Schmidt, 2008; Sallinen et al., 2004) with other research finding that reducing the amount of sleep that an individual usually requires by as little as two hours is sufficient to significantly decrease the individual’s subsequent performance and alertness (e.g. Dinges et al., 1997; Neri et al., 2002; Van Dongen, 2006). It could simply be that the number of calls reduces the sleep quantity of respondents to such a level.

It was found that both the amount and quality of sleep differ in the three on-call scenarios with the most damaging scenario being on-call and receiving callouts, followed by being on stand-by. As expected, receiving callouts is the scenario with the largest impact as sleep is being disrupted. Sleep disruption research has clearly shown that sleep fragmentation leads to both reduced sleep quantity and quality (e.g. Bonnet & Arand, 2003; Martin et al., 1996; Murray & Dodds, 2003). Similarly, as predicted, both higher number of callouts and the percentage of callouts that keep respondents awake for at least 30 minutes were shown to have a higher impact on the quality of sleep.

High number of disruption events has been identified by sleep research as one of the leading factors responsible for the deterioration of sleep quality (e.g. Bonnet & Arand, 2003; Martin et al., 1996; Murray & Dodds, 2003). The effect identified for callouts that keep respondents awake for 30 minutes or more on sleep quality and well-being are supported by sleep inertia research which has shown that when sleep inertia is overcome it then becomes more difficult to fall back asleep and leads to reduced well-being on the following days (e.g. Balkin & Badia, 1988; Miccoli et al., 2008; Wertz et al., 2006). Circadian disruption research has also found similar results where it has identified that disruption to circadian rhythms leads to sleep difficulties (Edéll-Gustafsson et al., 2002; Edéll-Gustafsson, 2002; Hakola & Härmä, 2001), especially through repeated disruption such as what occurs through on-call and shift work. Further to this, sleep research has also identified that both sleep stage and the degree to which sleep is consolidated also leads to reduced sleep quality and increased sleepiness on the following day (Stepanski, 2002). Although these factors were not assessed in this study they must still be expected to be present and to be of influence.

Similarly, sleep disturbance research has constantly identified a negative association between sleep disturbance (causing both reduced sleep quantity and quality) and psychological well-being, including clinical depression (e.g. Chu & Richdale, 2009; Goyal, Gay, & Lee, 2007, 2009; Sloan, 2008), supporting the significant results found. This is both due to sleep disruption and circadian disruption where research over the last several decades has clearly established a negative relationship between circadian disruption and well-being (e.g. Comperatore & Krueger, 1990; Costa, 2003; Sussman & Coplen, 2000). Identical results have been found between sleep disruption research (e.g. Bonnet & Arand, 2003) and on-call research (Heponiemi et al., 2008; Imbernon et al., 1993), where both sleep quality and sleep quantity have been found to have an impact on well-being.

As expected, sleep quantity was found to be affected by the number of call-outs. Correspondingly, sleep quality was found, as predicted, to be affected by anxiety. This was a relationship already hinted at by previous on-call research where high levels of anxiety due to worry about being woken up by an alarm were identified (Torsvall & Akerstedt, 1988). This is yet another relationship clearly identified by sleep research where the relationship between stress and reduced sleep quality is well documented (e.g. Akerstedt et al., 2004; Janssen & Nijhuis, 2004; Thorsteinsson & Brown, 2009).

Although the data collected in this survey does not allow the testing of the relationship between the timing of callouts and the impact felt on anxiety, fatigue, and the ability to fall back asleep, other evidence collected in both the survey and in Study 1 support such a relationship. Both the conviction by survey respondents that there is a period in which sleep disruption has a stronger effect (a conviction supported by sleep disruption research) and data collected from interviewees in Study 1 support the existence of such an effect.

The various Multiple Correspondence Analyses found that no agglomeration of respondents into sub-groups were present in socio-demographic factors, on-call arrangements, and in factors used to explore feelings towards on-call work. The non-existence of sub-groups of on-call arrangements leads to the conclusion that, although there is a degree of variation across the sample with regards to on-call arrangements, the general way on-call arrangements are prepared and managed is similar across Network Rail. These data confirm what the descriptive analysis had suggested as, for example, most respondents are required to maintain normal working hours (96.7% of respondents) and are required to work on-call (97.2% of respondents). Similar conclusions are also derived with regards to socio-demographic indicators and with regards to factors relating to feelings towards on-call work where little variation was found also.

Many interviewees in Study 1 indicated that they would not work on-call if they had a choice. The results of the questionnaire clearly show this to be the case across for the majority of on-call workers with 56% clearly stating they would definitely not work on-call if given the choice (1 = definitely not, 5 = definitely yes).

6.7 Framework iteration

This study analysed the generality of the most relevant findings of Study 1 and assessed the relationships between the factors in the three on-call scenarios identified previously. On-call arrangements, on-call management and procedures were tested for the three on-call scenarios identified and were assessed against outcomes. The findings were then used to iterate the framework previously developed and shown below in Figure 6.17. The results support some of the findings of Study 1 but not all and, further, identify cover arrangements and the need to maintain normal working hours as factors to consider at the planning and implementation phases of on-call work. Further support was found for the impact of on-call work on both sleep quality and quantity for all three scenarios. Satisfaction as a specific attitude to on-call work was defined and was found to be negatively associated with on-call work. These changes are shown in orange in the iterated framework. Individual factors were also tested and no influence was found between experience and age on on-call outcomes. Furthermore no differences were found for perceived performance between the on-call scenarios. Although it is expected that performance is affected by on-call work no comparison data were collected between on-call and not on-call events. These results are highlighted in red in the framework as although no supporting data for them was found in this study, the previous study has found support for them. Directed research into the effect of individual factors would provide data supporting the inclusion or exclusion of these factors into the framework. Unfortunately it is not one of the objectives of this thesis to explore that relationship in detail.

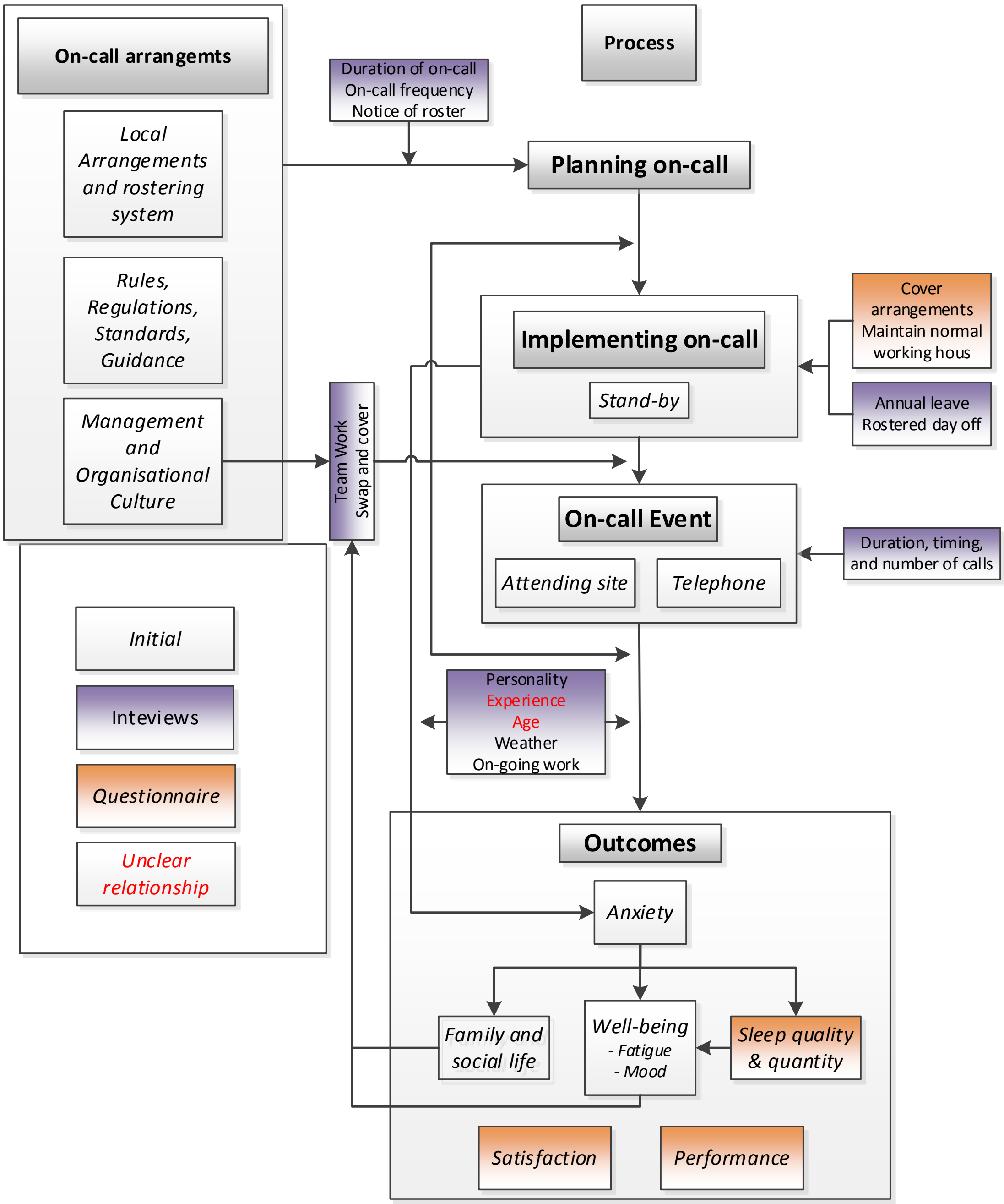


Figure 6.17 - Second iteration of on-call framework

6.8 Methodological implications

The analysis of the data collected in this study identified a number of specific relationships between on-call arrangements (e.g. frequency), on-call scenarios (e.g. stand-by) and on-call event factors on on-call outcomes (e.g. anxiety). These results were used both to iterate the on-call framework developed and to focus the scope and aims of Study 3 which aim to clarify the particular relationship between callouts and fatigue, stress and performance. For example, Study 3, by collecting real-time data regarding the number and timing of callouts, explores the premise that there is a worst time to be woken up, and explores its impacts on performance and well-being. Through the use of a diary these data were collected and these relationships were tested directly, i.e., collect timing of callouts and how able workers feel, at that point in time, to perform their duties.

6.9 Chapter Conclusion

The results of this second study support the majority of the findings of Study 1 and add further strength to the relationships identified in the framework between on-call arrangements, its outcomes and the factors involved on the different stages. The organisation of on-call work around the three different on-call scenarios identified in Study 1 is further supported and further details provided on the different impact on on-call outcomes in each of them. Results also support the differentiation of on-call work from other working hours arrangements and provide further evidence about the role of anxiety in this system of work.

The next chapter will discuss the third, and last, on-call specific research study performed for the thesis. It details the preparation, execution, analysis, and results from a two-week long questionnaire depicting both a week on-call and a week off-call performed with NR on-call maintenance managerial level staff.

Chapter 7 – Study 3: On-call diary

7.1 Chapter summary

This chapter discusses the third research study performed for this thesis. It details the preparation, execution, analysis and results of an on-call work diary. Similarly to the previous study, participants were Network Rail on-call maintenance managers. For this study participants were asked to record fatigue, anxiety, mood, and sleep data both during a non on-call week and an on-call week which can be further subdivided into two on-call scenarios; being on stand-by and receiving callouts. The chapter concludes with the methodological implications for future studies and for the iteration of the on-call framework developed.

7.2 Background

At Network Rail only *distal* on-call work scheduling is present and on-call work is described as the situation where a worker is waiting to respond to an emergency callout or answering a query from people working in the field (ORR, 2006). This was a system that was initially designed to ensure that in the event of emergencies during the periods between shifts, there would be a number of qualified workers available to provide expert advice or resolve any faults that might occur in the infrastructure.

On-call arrangements and the impacts of on-call work on staff were explored through the use of interviews in Study 1. The analysis of the data collected in Study 1 showed that week-long rosters are the preferred method of organising on-call work at Network Rail. These arrangements are managed locally and a great deal of freedom and flexibility is given to both frontline and managerial staff to swap, change, and cover rosters. These are coping arrangements that are frequently used by staff to help achieve work-life balance. It is the inherent unpredictability of on-call work that is the main differentiating characteristic of on-call work and other types of work schedules. Not knowing if and when a callout will occur leads on-call workers to the impossibility of organising their time, which subsequently causes workers to feel anxious. Furthermore, workers feel this anxiety then affects their quality of sleep and as a result causes their fatigue levels to rise. The unpredictability of when a callout might be received can also become paralysing and prevent many workers from maintaining their *normal* lives, irrespective of whether they actually receive a call or not, due to the potential that they might be disturbed and required to spend long periods of time on the phone or attending the fault. What is more, the sleep disruption caused by callouts during the night and its subsequent impact on fatigue and performance are major concerns resulting from on-call work. Although only a small number of interviewees perceive their abilities to be severely impaired, research has identified a clear relationship between sleep loss, fatigue, and performance (e.g. Kaida et al., 2007; Van Dongen et al., 2003).

Study 1 also identified managerial staff as being more at risk than frontline staff, where the 12 hours rest policy is enforced for most, and the sleep time concept for the remainder, but managers are left to manage their own working hours. Although fatigue management research shows that these are not ideal arrangements, frontline workers' fatigue risk is reduced when compared to that of managers (e.g. Knauth, 1996; Knauth & Hornberger, 2003; Rosekind et al., 1995; Spencer, Robertson, & Folkard, 2006). For on-call managerial level staff, the organisational culture pressure to always possess all the knowledge regarding their depot and the need to keep their daily appointments, means that many managers choose not to, or are unable to, take a period of rest after being called-out. Furthermore, due to the expectation put on them, managers many times choose not to turn off their phones when not on-call so that they can both get involved in faults and be available to provide help to needing on-call co-workers. This leads to managers also receiving a number of callouts when not on-call.

For these reasons it was decided that Study 2 would focus only on on-call managerial staff who were perceived as being more at risk. To explore this group, a survey questionnaire was developed and rolled-out to the whole of Network Rail's Infrastructure Maintenance organisation. The results of the survey supported the view that on-call managerial staff feel the need to maintain *normal working hours* possibly due to the managerial appointments identified in Study 1 (e.g. meetings).

The survey also demonstrated that rosters are the most common way to schedule on-call work and that, within this arrangement, week-long rosters are the preferred method. As predicted, based on the findings of Study 1, the majority of on-call rosters are not aligned with other working hours arrangements in place at the company. This means that it is possible for on-call workers to be on a rostered day off, or on annual leave, and still be rostered and required to work on-call. When this occurs it is usually the worker himself that must find a solution to this problem. This is usually achieved by swapping the shift with a co-worker. Not surprisingly, a large number of respondents reported having worked on-call for longer than 12 hours before and around 70% reported have previously worked periods longer than 17 hours. Predictably, satisfaction with on-call work was found to be dependent on the amount of free time for social life aspects, and the longer the maximum period working on-call the lower the satisfaction with the amount of time on-call work leaves managers for their personal lives. Since many times there is no one who can relieve whoever is on-call or those than can (the next on-call level up) are also asleep, it is not surprising that managers choose to deal with the fault for such long periods of time.

Study 2 also found that both the amount and quality of sleep differ in the three on-call scenarios with the most damaging scenario being on-call and receiving callouts, followed by being on stand-by. As expected, receiving callouts is the scenario with the larger impact as sleep is actively being disrupted. When on stand-by, feelings of anxiety about being called-out were also found to impact both the quality and quantity of sleep. This goes some way to explain the reduced quantity and quality of sleep experienced by on-call staff. These results were not unexpected as the relationship between stress and quality of sleep has been well documented in research (e.g. Burgard & Ailshire, 2009; Morin, Rodrigue, & Ivers, 2003), and such a relationship had also been mentioned by interviewees in Study 1.

It was also found that respondents are better able to deal with a small number of callouts (0% to 25%) and that a higher volume of calls has more damaging effects to perceived well-being. Similar results were found with regards to the number of callouts when on-call and the percentage of callouts when already asleep, with respondents experiencing higher levels of fatigue and stress when receiving a higher number of callouts. Study 1 indicates this is probably due to the inability to relax after receiving a number of callouts, from worrying about decisions made, or due the timing of the call itself. Sleep disruption research has also suggested that disruption in the deeper stages of sleep is more damaging to both the quality of sleep and the ability to fall back asleep (e.g. Bonnet & Arand, 2003; Pinel, 1992; Tassi & Muzet, 2000). This also explains why most respondents feel the worst time to be called-out is in the first four hours of sleep, as this period corresponds to the period of deeper sleep (Pinel, 1992). It is also the period when we would expect to see more sleep inertia and deteriorated abilities (Tassi & Muzet, 2000; Wertz et al., 2006). In line with this research, it was somewhat surprising that respondents do not feel a strong impact on their performance when being called-out and that respondents feel their performance deteriorates to a greater degree when providing a telephone consultation than when attending site. A possible explanation for this could be that the act of leaving the house helps workers to overcome inertia (e.g. Miccoli, Versace, Koterle, & Cavallero, 2008; Wertz et al., 2006).

Contrary to what interviewees in Study 1 believed, Study 2 found no relationship between on-call experience (the number of years working on-call) and both the anxiety felt when on-call or the impact felt on the quality of sleep when on stand-by and when receiving callouts. In the same line Study 2 also did not find any relationship between age and quality of sleep in any of the on-call scenarios researched.

Both Study 1 and Study 2 used methods that required participants to recollect the data from previous experience (interview and questionnaire recalling the general experience of working on-call). Recollection bias is a known issue with these types of studies as it is known that human memory is far from exact (e.g. Bolger, Davis, & Rafaeli, 2003; Staal, 2004; Stone & Shiffman, 2002). To overcome this limitation Study 3 aimed to collect real-time data, and in turn gather further evidence to support the findings of Study 1 and 2 and to further explore the idiosyncrasies of on-call work.

The principal aim of Study 3 was to collect callout data, at the moment of their occurrence, and the collection of the perceived impact of these callouts on workers' fatigue, anxiety, and mood. This was achieved by exploring objectives three to six of this thesis, described in section 1.2 Aims and Objectives of Chapter 1 and to attempt to answer the research questions related to each objective described in Table 3.1 (chapter 3) and replicated below.

	Research questions
Objective 2	• What are the main impacts of on-call work? • How do workers deal with these impacts?
Objectives 3 and 4	• What are the on-call factors that lead to consequences and how do they interact? • What are the callout related factors that lead to unwanted consequences of on-call work?
Objective 5	• How can the negative impact of the most damaging factors be reduced in Industry?

This chapter will now discuss in detail the method and results of Study 3, discuss their implications for this thesis and for future studies, and expose how these findings were used in the final iteration of the on-call framework.

7.3 Hypotheses

The diary, being based on previous findings, and designed to explore specific hypotheses, allowed the construction of a list of hypotheses.

Study 2 found significant differences for all sleep related factors between working on-call and not working on-call with sleep during the on-call week being consistently reported as being more affected (refer to section 6.5.4 Sleep for more details). These results were aligned with those of Study 1 where interviewees stated that sleep was one of the main factors affected by on-call work (for more details refer to sections 5.4.3 Theme 3: Receiving callouts, (1) Sleep Disruption) and 5.4.2 Theme 2: Stand-by, (1 2) Consequences). More than this, literature into on-call work has also consistently identified sleep as being affected by on-call work (Saxena & George, 2005; Smithers, 1995; Torsvall & Akerstedt, 1988). It is, as such, hypothesised that:

On-call versus not on-call

hypothesis 1. sleep quantity will be significantly different in the on-call week and in the non on-call week

hypothesis 2. sleep quantity will be significantly different between receiving callouts and stand-by and not being on-call

hypothesis 3. sleep quality will be significantly different in the on-call week and in the non on-call week

hypothesis 4. sleep latency will be significantly different in the on-call week and in the non on-call week

Similar results were found with regards to anxiety, fatigue and mood both in Study 2 (refer to 6.5.3.2 Impacts of on-call work on well-being, 6.5.6 Mood and Motivation) and in Study 1, where anxiety, fatigue and mood were identified as some of the main negative outcomes of on-call work (refer to section 5.4.2 Theme 2: Stand-by, (1) Anxiety for more details). It is expected that:

hypothesis 5. anxiety at the end of normal shift / start of an on-call shift will be significantly different in the on-call week and the non on-call shift week

hypothesis 6. fatigue at the end of normal shift / start of an on-call shift will be significantly different in the on-call week and the non on-call week

hypothesis 7. mood at the end of normal shift / start of an on-call shift will be significantly different in the on-call week and the non on-call week

hypothesis 8. anxiety in the morning will be significantly different in the on-call week and the non on-call shift week

hypothesis 9. fatigue in the morning will be significantly different in the on-call week and the non on-call week

hypothesis 10. mood in the morning will be significantly different in the on-call week and the non on-call week

Study 1, surprisingly, found that even when not working on-call, many workers still state receiving call-outs (refer to section 5.4.5 Theme 5: Not on-call for more details). It is, as such, expected that:

hypothesis 11. callouts will occur both during the on-call week and the non on-call week

Fatigue as an unwanted consequence of working hours systems of work has been found to have a cumulative component (e.g. Spencer et al., 2006). Interviewees in Study 1 also felt under the influence of this component stating that fatigue increases throughout the on-call week (refer to section 5.4.3 Theme 3: Receiving callouts, (3) Fatigue for more details). Interviewees also mentioned a similar effect with regards to anxiety where at the end on the week, contrary to what happens with fatigue, anxiety levels drop (refer to section 5.4.2 Theme 2: Stand-by, (1 2) Consequences for more details). It is, therefore, hypothesised that:

Cumulative

hypothesis 12. fatigue end of normal shift / start of an on-call shift when on-call will be significantly different between the days of the on-call week

hypothesis 13. anxiety end of normal shift / start of an on-call shift when on-call will be significantly different between the first six days and the last day of the on-call week

Shiftwork literature has found some support for the role of experience and the ability to deal with the negative consequences of shift work (Duclos et al., 2012; Gillberg et al., 2003) and for the effects of age, where some evidence has been found that older workers can find it harder to work shifts (e.g. Costa & Di Milia, 2008; Harma, 1996; Pires et al., 2009). These effects were also mentioned by interviewees in Study 1 who feel they become more able to deal with the negatives of on-call work through experience (refer to section 5.4.2 Theme 2: Stand-by (1 1) Causes). Study 2 found no significant results regarding the roles of experience and age. Based on these mixed results and on the limitations of Study 1 and Study 2 (mainly recollection bias but refer to section 8.8 Limitations in Chapter 8 for more details) it was decided to assess experience and age in this study as well. It is, therefore, hypothesised that:

Experience and age

hypothesis 14. anxiety at the end of normal shift / start of an on-call shift when on stand-by will be significantly affected by experience (years working on-call)

hypothesis 15. sleep quality when on stand-by will be significantly affected by experience (years working on-call)

hypothesis 16. sleep quantity when receiving callouts will be significantly affected by experience (years working on-call)

hypothesis 17. anxiety at the end of normal shift / start of an on-call shift when on stand-by will be significantly different between different age groups

hypothesis 18. sleep quality when on stand-by will be significantly different between different age groups

Torsvall & Akerstedt, (1988) when investigating ship engineers' on-call work found that low sleep quality was caused by the expectation of hearing alarms which in turn lead to high levels of fatigue in the morning. Further support for this was found in Study 1 where interviewees identified anxiety as one of the main causes for poor sleep quality (refer to section 5.4.2 Theme 2: Stand-by, (1) Anxiety for more details) and fatigue as one of the main outcomes of working on-call (refer to 5.4.2 Theme 2: Stand-by, (1 2) Consequences for more details). Similar results were found by Study 2. Stress related literature has also found that a high number of stressful life events leads to higher levels of fatigue and that this relationship was mediated by low quality of sleep (Thorsteinsson & Brown, 2009). In accordance with these findings, it is hypothesised that:

Anxiety and sleep

hypothesis 19. fatigue in the morning when on-call will be affected by anxiety at the end of normal shift / start of an on-call shift

hypothesis 20. sleep quality when on-call will be affected by anxiety at the end of normal shift / start of an on-call shift

hypothesis 21. fatigue in the morning when on-call will be affected by sleep quality

hypothesis 22. sleep quality when on-call will mediate the effect of anxiety at the end of normal shift / start of an on-call shift on fatigue in the morning

hypothesis 23. fatigue in the morning when on-call will be affected by sleep quantity

hypothesis 24. sleep latency when on-call will be affected by anxiety at the end of normal shift / start of an on-call shift

From Study 1 it is expected that number of calls and percentage of calls that disrupt sleep are the main callout associated factors that lead to negative consequences (refer to section 5.4.3 Theme 3: Receiving callouts for more details). These results were further supported by Study 2 where relationships between number of callouts and fatigue, stress, and performance was identified (refer to section 6.5.8.3 Callouts and Fatigue, Stress, and Performance (hypothesis 45 to hypothesis 52) for more details). Study 2 participants also highlighted that calls received between zero and four hours into their sleep period have a greater impact. Time of callout related tests however found no significant effects on any of these factors. Sleep disruption research has identified that sleep fragmentation has as deleterious effect on sleepiness and performance. However, similarly to the results found on this thesis it has not shown an effect between time of day and unwanted outcomes (e.g. Baker & Olson, 1994; Haire et al., 2012; Murray & Dodds, 2003; Van der Hulst et al., 2001). On the other hand, disruption to the deeper stages of sleep has been found to be more damaging to both the quality of sleep and the ability to fall back asleep (e.g. Bonnet & Arand, 2003; Pinel, 1992; Tassi & Muzet, 2000). Based on these findings it is therefore hypothesised that:

Callouts

hypothesis 25. amount of time required to get back to sleep after a callout when on-call is affected by the length of callouts

hypothesis 26. quality of sleep when on-call and receiving callouts is significantly different between short callouts (10min or less) and longer callouts

hypothesis 27. mood in the morning when on-call and receiving callouts is significantly different between short callouts (10min or less) and longer callouts

hypothesis 28. ability to perform duties (performance) is statistically different between callouts received whilst awake or asleep

hypothesis 29. sleep quality is statistically different between callouts received whilst awake or asleep

hypothesis 30. time asleep is statistically different between callouts received whilst awake or asleep

hypothesis 31. bed time is statistically different between callouts received whilst awake or asleep

hypothesis 32. amount of time required to fall back asleep after a call out is statistically affected by time of day (or night)

A sleep disruption review using the results of eight studies has identified a logarithmic relationship between sleepiness and rate of sleep fragmentation. Results show that a rate of periodic fragmentation of about 20 minutes has the greatest impact (Bonnet & Arand, 2003). As such, it is hypothesised that:

hypothesis 33. ability to perform duties (performance) is significantly different for different sleep fragmentation rates

Study 2 found clear support for the hypothesis that well-being and number of callouts are related. This had already been identified by interviewees in Study 1 who also mentioned sleep as being affected by on-call work, and much more so when receiving call-outs than when only on stand-by (refer to section 5.4.4 Theme 4: Responding to callouts for more details). Research has also hinted at a similar relationship (although no direct research into on-call work has assessed call related factors such as number of callouts). Receiving callouts disrupts sleep which is the key human biological function affected by on-call work and sleep disruption has been linked to fatigue (e.g. Bonnet, 1985; Bonnet & Arand, 2003; Stepanski, Lamphere, Badia, Zorick, & Roth, 1984), alertness (e.g. Martin et al., 1996; Powell et al., 1999), and stress (e.g. Bennett et al., 1999; Mcnamara et al., 2006; I. Smith & Shneerson, 1995), to mention but a few factors affected by sleep. In alignment with this research it is therefore hypothesised that:

hypothesis 34. fatigue in the morning when on-call is statistically affected by number of callouts

hypothesis 35. anxiety in the morning when on-call is statistically affected by number of callouts

hypothesis 36. mood in the morning when on-call is statistically affected by number of callouts

hypothesis 37. fatigue in the morning when on-call is statistically affected by time of day callouts occur

hypothesis 38. fatigue in the morning when on-call is statistically affected by amount of time after going to sleep that callouts occur

7.4 Method

A digital format diary was produced to collect data across Network Rail's Infrastructure Maintenance managerial staff. For details on the creation and organisation of the diary please refer to Chapter 4.

7.4.1 Selection method

All participants of Study 2 were invited to participate in Study 3. At the end of Study 2 there were 148 participants willing to take part in Study 3. Of these 37 were still willing to participate at the beginning of Study 3 two months after the completion of Study 2. At the end of the collection period in June 2012 a total of 31 participants had completed the protocol. Of these, the data of 26 were deemed usable for analysis (see section 7.4.3 Data preparation and analysis, below).

7.4.2 Procedure

For the duration of the study (one on-call week and one not on-call week) participants were asked to provide ratings of anxiety, fatigue, and mood at the end of their *normal* hours day of work (for each day of the study – 14 days in total), which also marks the beginning of the on-call period (when on-call). Anxiety, fatigue, and mood scores were collected using a 5-point rating scale where 1 = Not anxious/fatigued at all, Very good mood; 5 = Very anxious/fatigued, Very bad mood.

Participants were also asked for these scores the morning after each night, together with their sleep related indicators. These were their bed time, the estimated time of falling asleep, the getting up time, and the sleep quality for that night. Sleep quality was recorded using a 5-point rating scale where 1 = Very good quality of sleep, 5 = Very poor quality of sleep. From the sleep data, sleep quantity was then calculated by subtracting the getting up time from the time of falling asleep.

Participants were also asked to record the time each callout occurred (when one occurred), the time when it was completed, if they were asleep at the time of the callout, if the call required attendance (versus only requiring liaising over the telephone), how able they felt to deal with the callout (performance estimate), and the estimated time of falling back to sleep afterwards (BTS – back to sleep). Table 7.1 presents the table used to collect the diary data and further details can be found in the diary manual in Appendix C – Diary protocol.

Table 7.1 - Diary table

At the beginning of on-call shift		
Anxiety	Fatigue	Mood

For each callout record:						
	Time	Ended	Asleep	Out	Ability	BTS
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

In the morning:			
In bed at	Asleep	Got Up at	Sleep quality

Anxiety	Fatigue	Mood

NOTE	1 = Low / Good	5 = High / Bad

Participants were sent a daily email requesting the previous day diary together with a new clean spreadsheet. This method was elected as it would both work as a reminder for the participants to send in their data to the researcher and allowed the researcher to monitor the progress of each participant, identifying (and when possible correcting) any issues or misconceptions about the diary.

As discussed in detail in Chapter 4, the diary was designed to be run on Blackberry telephones as it was the researcher's understanding at the time that all managerial level Infrastructure Maintenance staff were issued with one as company policy. This was not the case and two participants did not possess a Blackberry telephone (one had an old Nokia telephone and the other had a Smartphone). The participants chose to take part in the study nonetheless and collected their data on print-outs of the diary. Similarly to the remaining participants, these participants were asked to digitise and send the printouts back to the researcher daily.

7.4.3 Data preparation and analysis

The data capture and analysis process was in four stages.

Stage 1: Data collection: All data was collected through a diary protocol during one on-call week and the following not on-call week.

Stage 2: Preparation of data for analysis: All recorded data was transferred to SPSS and scanned initially for mistakes and errors, which were corrected where possible. Where correction was not possible these data were transformed into missing data so that they would not distort results.

Stage 3: Descriptive statistics: All variables were analysed, a description of the results found was produced, and the differences found between the different on-call scenarios were analysed and described.

Stage 4: Multivariate statistics: At this stage the data was tested for relationships between the different factors and for the effects different effects have on the effects identified in the on-call framework.

During the data collection period each participant's data were collected and compiled into a Microsoft Excel spreadsheet. Upon the completion of the study the data were transferred to the Statistical Package for Social Sciences (SPSS) and prepared for analysis using the procedure described above. All data analysis was performed using SPSS version 20.0.

7.4.3.1 Data management

There were a number of issues with the data collected and, as a result, it was necessary to clean the data in preparation for analysis. The majority of the participants' on-call rotas followed the *1 in n* rotation, however, four participants worked on-call for two weeks instead of one (2 in *n)*. For those participants, the second on-call week was disregarded and the only data kept and used was that of the first week and that of the week not on-call. A further three participants worked non-weekly on-call schedules and, as such, these data were removed from the analysis as no comparison could be drawn from this data. A further two participants chose, or were required to work the night shift during their on-call week. To maintain consistency their data was also removed leaving a total of 26 cases for analysis. One participant did not provide data for the not on-call week but it was decided to include the data regarding the on-call week in the analysis.

In accordance with the findings of Study 2, timing of callouts was calculated both by time of day and by amount of time after going to sleep. To make the data manageable, when conducting the analysis for time of day, timing of callouts was recoded into two-hour blocks as the number of calls was not very high (section 7.5.3 Callouts provides further details). This granularity retains a good level of detail that supports the analysis in terms of the callout timing factors identified in Studies 1 and 2 (e.g. calls have a higher impact in the first few hours of sleep – 22h to 02h). Category one incorporated calls received between 00:01 and 02:00, category two, calls received between 02:01 and 04:00, and so on. Similarly, the amount of time after going to sleep was also recoded into two hour categories using the same procedure. Participants from Study 2 indicated that being woken two to four hours after falling asleep has the most damaging effects.

To test hypothesis 33 a procedure to calculate the sleep fragmentation rate was devised in which sleep fragmentation equals the average of (time call 1 – time asleep), (time back to sleep call 1 – time call 2), (time back to sleep call 2 – time call 3), etc.

Only two of the three on-call scenarios were investigated in this study. No distinction was made between calls that were dealt with over the telephone and those that required the participant to attend as less than 10% of calls required attendance. This scenario is referred to as *receiving callouts* across this chapter. The stand-by scenario represents the remaining days of the on-call week (where no callouts were received).

Contrary to sleep quantity when on-call, not on-call, and on stand-by, where the time from receiving a callout to falling back asleep were not included in the calculations, sleep quantity when receiving call-outs was calculated by removing the amount of time participants were awake after a callout. Quantity of sleep when receiving callouts was then calculated by subtracting the time participants got up from the time they fell asleep, and then subtracting any amount of time when they were awake in the night dealing with callouts. This is, Quantity of sleep = (Time up – time asleep) – (amount of time up due to callout 1 + amount of time up due to callout 2 + amount of time up due to callout n).

7.5 Results

Some sample description data is presented. Then, similarly to the arrangement of the study, the data was then analysed and is reported here based primarily on the three main sections of the diary; *At the end of a normal working day*, *Callouts*, and *In the morning*. Within each of these, results firstly compare the two weeks of the study (on-call week and not on-call week). Then, where applicable, the on-call week is separated into on-call scenarios (not on-call, on stand-by and receiving a callout) and the scenarios are also compared. The scores of each factors analysed represent the average results for the seven on-call days and the seven not on-call days of the study. The exception to this being the cumulative effect section where the scores of each day are compared independently.

7.5.1 Sample description

At the beginning of the data analysis procedure the data of 26 participants was compiled. Respondents have worked on-call for an average of eight years (SD = 4.3) with a minimum of six months and a maximum of 17 years. Most respondents (61%) have worked in the rail industry for 20 years or more and none have worked in the rail industry for less than six years. Most respondents have been in their current position for between one and five years (46.4%) and 42% have been in their current position for at least six years. All participants were male and the majority are between 35 and 44 years of age (59%) with 25% being between 45 and 56 years of age and only a minority (6.9%) being either over 56 or under 25 years of age. Respondents work an average of 46 hours per week including overtime (SD = 6 hours) working a maximum of 55 hours and a minimum of 35 hours and with 25% of them working 40 hours per week or less. On-call rosters varied from one week in two to one week in eight, with one week in four being the most common roster (27.6%) followed by one week in six (24.1%). In total, during the two weeks of the study, 357 shifts were monitored, 182 of which were on-call shifts.

7.5.2 At the end of the normal working day / start of on-call shift

Both during the on-call and not on-call week participants were asked to provide ratings of anxiety, fatigue, and mood at the end of their normal working day, which also marks the beginning of the on-call period for the week where the participant was on-call. The section starts by describing the general findings for both the on-call week and the non on-call week. This is followed by an analysis of the data through the three on-call scenarios.

The results throughout this section represent the average scores of all the seven days of data collected when on-call for all participants and for the seven days of data collected when not on-call.

Table 7.2 below presents the results of the anxiety, mood, and fatigue scores for both the on-call and the not on-call week. Paired T-tests determined that the scores given with regards to anxiety, fatigue, and mood, at the beginning of the on-call shift / end of normal shift were significantly different when on-call and when not on-call, supporting hypothesis 5, hypothesis 6, and hypothesis 7.

Table 7.2 - Anxiety, fatigue, and mood at the end of *normal* shift when on-call and when not on-call (1 = Not anxious/fatigued at all, Very good mood; 5 = Very anxious/fatigued, Very bad mood)

Factor		Not on-call	On-call	T-test result
Anxiety	M	**1.46**	**2.01**	$t(22) = 4.606^{***}$
	SD	0.64	0.87	
Fatigue	M	**1.97**	**2.38**	$t(22) = 3.038^{**}$
	SD	0.72	0.72	
Mood	M	**1.57**	**2.24**	$t(22) = 5.030^{***}$
	SD	0.74	0.76	

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

To investigate the existence of cumulative effects throughout the on-call week (hypothesis 12 and hypothesis 13), fatigue and anxiety scores for each day at the beginning of the on-call shift / end of normal shift were compared.

Repeated-measures ANOVAs with Greenhouse-Geisser correction for each factor were performed. Helmert analysis contrasts identified significant differences between day seven and the previous six days thus supporting hypothesis 13, which predicted that anxiety scores would be statistically different between the first six on-call days and the last (seventh) day ($F(1,20) = 8.215$, $p < 0.01$). These results indicate that there is a reduction in anxiety at the end of the on-call week as predicted by the interviews conducted for Study 1.

Fatigue scores, however, revealed no statistically significant differences not supporting hypothesis 12 which predicted that fatigue end of normal shift / start of an on-call shift when on-call will be significantly different between the days of the on-call week. These results are presented below in Table 7.3.

Table 7.3 - Cumulative effects of anxiety, fatigue, and mood during the on-call week

Factor		***On-call*** D1	D2	D3	D4	D5	D6	D7	ANOVA
Anxiety	M	**2.24**	**1.86**	**2.14**	**1.90**	**1.90**	**2.19**	**1.52**	F(3.880, 77.594) = 3.082*
	SD	1.14	0.96	1.28	1.10	1.00	1.29	0.68	
Fatigue	M	**2.15**	**2.25**	**2.35**	**2.70**	**2.70**	**2.65**	**2.40**	F(4.441, 84.380) = 1.152
	SD	1.04	1.02	1.18	1.17	1.13	1.04	1.23	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

7.5.2.1. Stand-by, Called-out, Not on-call

To further explore the statistically significant differences between anxiety, fatigue, and mood scores when on-call and not on-call, the on-call week data scores were divided into the on-call scenarios identified in Study 1: *stand-by* (on-call without receiving callouts) and *receiving callouts* (on-call and actually receiving callouts). It was hypothesised that these would reveal further insight into the relationships between factors.

Table 7.4 below presents the results of the anxiety, mood, and fatigue scores for the stand-by data, the called-out data and the not on-call week. To explore the significance of the differences between these scores, three repeated measures ANOVAs with Greenhouse-Geisser correction were performed.

Table 7.4- Anxiety, fatigue, and mood at the end of the *normal* shift / start of an on-call shift when on stand-by, receiving callouts, and when not on-call (1 = Not anxious/fatigued at all, Very good mood; 5 = Very anxious/fatigued, Very bad mood)

Factor		Not on-call	Stand-by	Called	ANOVA
Anxiety	M	**1.71**	**1.96**	**2.44**	F(1.456, 20.379) = 5.005*
	SD	0.64	0.96	1.18	
Fatigue	M	**2.14**	**2.37**	**2.30**	F(1.860, 26.040) = 0.759
	SD	0.77	1.09	0.79	
Mood	M	**1.72**	**2.32**	**2.56**	F(1.798, 25.178) = 9.480**
	SD	0.84	0.99	0.82	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

Paired comparisons were performed to assess the differences between on-call scenarios and not being on-call for the significant factors. The results reveal that anxiety scores are statistically different between not being on-call and receiving callouts ($F(1, 14) = 3.399$, $\rho < 0.05$) and that mood is not significantly different between on-call scenarios ($F(1, 14) = 2.115$, ρ = n.s.) but that both stand-by ($F(1,14) = 7.342$, $\rho < 0.05$) and being called-out ($F(1,14) = 16.632$, $\rho < 0.01$) are significantly different from not being on-call. Figure 7.1 below presents a visual representation of these results.

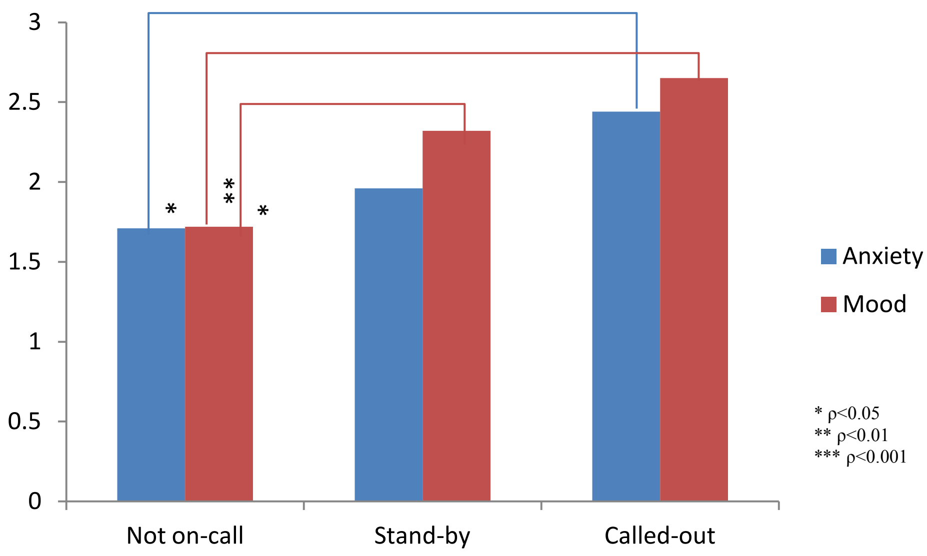


Figure 7.1 - Planned comparisons for anxiety and mood at the end of normal shift / start of on-call shift when on stand-by, called-out, and not on-call

There were not sufficient cases to run repeated measures ANOVAs to test the existence of a cumulative effect per on-call scenario. Participants were not exclusively on the stand-by scenario or on the receiving callouts scenario across their on-call week. Some days participants would receive no callouts (stand-by) whilst on others they would receive callouts. In effect, there were only three cases when participants fell into one scenario or the other. Consequently, no cumulative analysis could be performed per on-call scenario.

7.5.3 Callouts

This section discusses the data collected regarding the callouts participants received. As discussed in 7.4.2 Procedure, for the duration of the study, participants were asked to record:

- the time they received a call,
- the time the call ended (to calculate call length),
- if they were asleep or not,
- if they were required to leave the house,
- how able they felt to deal with the callout,
- how long it took to fall back asleep (if sleeping at the time of the callout).

A total of 204 callouts were recorded with 138 of these taking place during the participants' on-call week and the remaining 66 during their not on-call week. This is in accordance with hypothesis 11. On average each participant received 0.76 (SD = 0.77) calls per night during their on-call week and 0.36 (SD = 0.68) during their not on-call week. The large majority of all calls took place before the participants were asleep (78.9%) and only 9.8% of all 204 calls required participants to leave the house. There was, however, a large variance in the number of calls received by each participant with four of the participants actually receiving more callouts during the not on-call week than during the on-call week and two participants not receiving any calls on either week. A visual illustration of the large variation found is displayed in Figure 7.2.

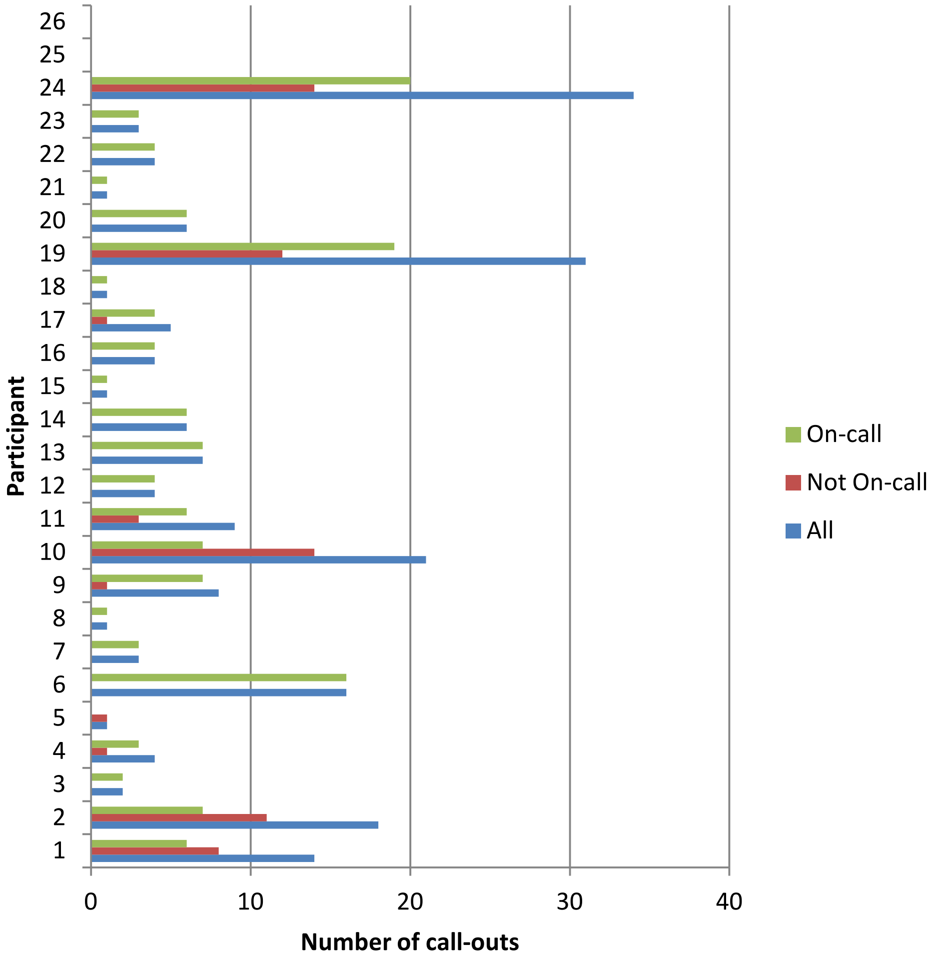


Figure 7.2- Number of calls per participant

The calls lasted an average of 25 minutes (SD = 52 min) and the amount of time required to fall back asleep was on average 53 minutes (SD = 46min). It is important to remember that the participants were asked to count as one call all the calls they were required to make to deal with the reason of the callout "if you are required to make several phone calls to deal with one callout you should only record the one original callout" (see Appendix C – Diary protocol for further details). Due to this the maximum call length recorded by the participants is as high as 5h50min with the median call being seven minutes, and 90% of the callouts lasting one hour or less. Callouts were received at all hours of the day with calls occurring during the day representing callouts received during the weekend. Similarly, the maximum time required to fall back to sleep was three hours with the median time of 40 minutes, and with 28% of calls requiring an hour or more for participants to fall back asleep. In accordance with the data analysis process described in section 7.4.3.1 Data management, timing of callouts was grouped into two hour blocks.

The highest peak in the number of callouts received occurs between 22h01 and 24h00 accounting for 14.7% of all callouts with 49% of all calls taking place between the end of the normal working day at 16h01 until 24h00. For the not on-call week callouts present a more homogeneous distribution is present with the number of calls across the on-call week being more homogenous across the 24 hours. Figure 7.3 shows a visual representation of these results.

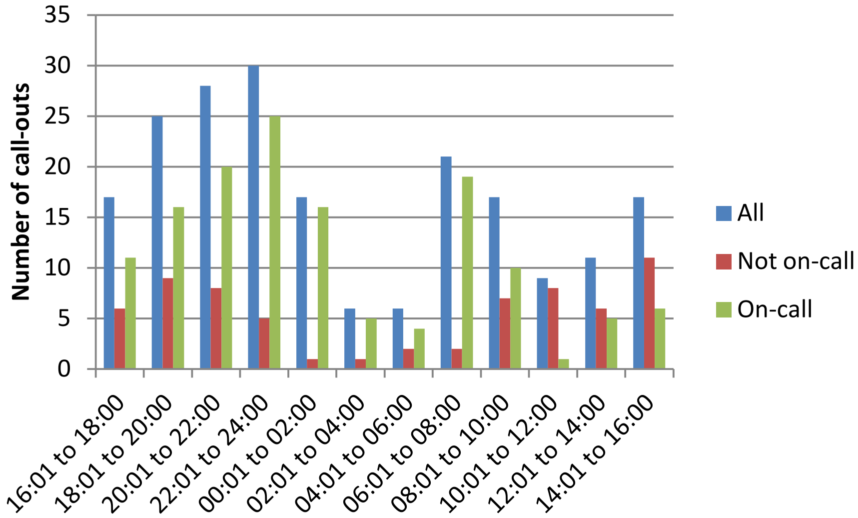


Figure 7.3 - Timing of calls when on-call, not on-call, and both

7.5.3 In the morning

In the morning, after each on-call shift, participants were asked to, once more, provide ratings of anxiety, fatigue, and mood. Participants were, however, also asked to provide ratings regarding the length and quality of their sleep. This section starts by describing the general findings of these factors for both the on-call week and the non on-call week. This is followed by an analysis of the data through the three on-call scenarios.

7.5.3.1 Sleep

Contrary to what could be expected based on Study 1, when on-call and not on-call, sleep indicators did not vary much (in absolute terms). To assess if the differences were statistically different paired t-tests were performed. The results of the tests did not find any significant differences for sleep quantity or sleep latency when on-call and not on-call. This is contrary to hypothesis 1 and hypothesis 4 that predicted that differences would be found between sleep quantity and sleep latency when on-call and not on-call. Sleep quality (1 = "very good" to 5 = "very poor"), on the other hand was found to be significantly different on average between the on-call week and the not on-call week, supporting hypothesis 3. Table 7.5 shows the results of these tests.

Table 7.5 - Sleep factors when on-call and not on-call (Sleep quality varies between 1 = Very good and 5 = Very poor)

Factor		Not on-call	On-call	T-test result
Bed time	M	**22h 58min**	**23h 8min**	t(22) = 0.673
	SD	57min	1h 11min	
Up time	M	**6h 45min**	**6h 32min**	t(22) = 1.310
	SD	37min	47min	
Sleep latency	M	**23 min**	**31 min**	t(22) = 1.212
	SD	26 min	14 min	
Sleep quantity	M	**7h 31min**	**7h 2min**	t(20) = 5.030
	SD	1h 5min	41min	
Sleep quality	M	**2.01**	**2.52**	t(22) = 2.586*
	SD	0.77	0.66	

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

Interestingly, a large variation was found regarding each of the sleep indicators both when on-call and when not on-call. For example, bed times for the on-call week were found to vary between around 21:40 and 02:40 and between 21:20 and 00:45 during the not on-call week. The reasons for this can be either personal or professional but regardless of which it seems not to have an effect on participants' sleep indicators.

Similarly to the previous section, to further explore these differences the on-call week scores were also divided into two on-call scenarios: *stand-by* and actually *receiving callouts* as it can be expected that receiving call-outs will lead to more sleep indicators to differ, especially sleep quantity due to sleep disruption (hypothesis 2). Once more, no distinction was made between calls that were dealt with over the telephone and those that required the participant to attend as less than 10% of calls required attendance.

To explore the differences between sleep scores when on stand-by, when receiving callouts, and when not on-call, five repeated measures ANOVAs with Greenhouse-Geisser correction were performed. As expected, sleep quantity was found to be significantly different between the three conditions tested. All other sleep indicators were not found to vary significantly. Results are presented below in Table 7.6.

Table 7.6 - Sleep factors per on-call scenario (Sleep quality varies between 1 = "very good" and 5 = "very poor")

Factor		Not on-call	Stand-by	Called-out	ANOVA
Bed time	M	**22h 58min**	**23h 15min**	**23h 08min**	$F(1.994, 35.900) = 0.713$
	SD	59min	1h 29min	1h 15min	
Up time	M	**6h 41min**	**6h 40min**	**6h 45min**	$F(1.487, 25.272) = 0.872$
	SD	38min	50min	1h 04min	
Sleep latency	M	**23 min**	**26 min**	**21 min**	$F(1.840, 16.562) = 0.530$
	SD	11min	17 min	15 min	
Sleep quantity	M	**7h 29 min**	**7h 06 min**	**6h 31 min**	$F(1.756, 26.341) = 4.177$*
	SD	1h 10 min	18 min	49 min	
Sleep quality	M	**2.22**	**2.38**	**2.63**	$F(1.934, 34.820) = 2.103$
	SD	0.75	0.69	0.98	

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

Paired comparisons were performed to assess the differences between on-call scenarios and not being on-call for sleep quantity. Results reveal that sleep quantity when receiving callouts is significantly different from sleep quantity when not on-call ($F(1, 15) = 9.671$, $\rho < 0.01$) supporting hypothesis 2. Figure 7.4 below presents a graphical representation of these results.

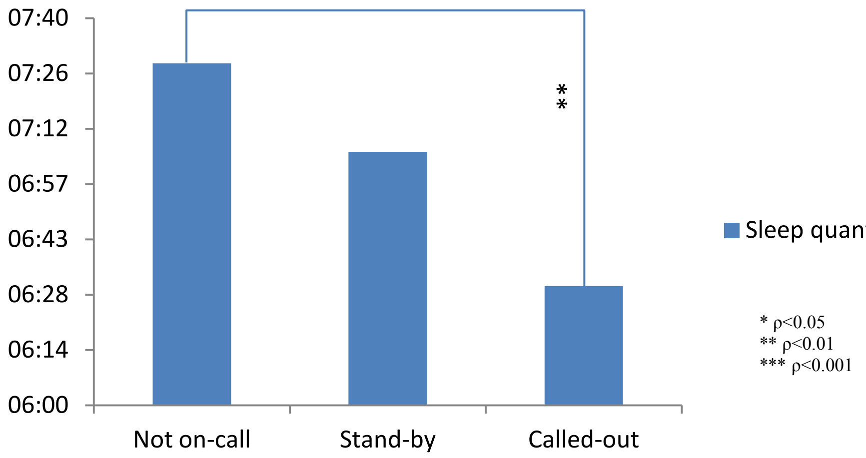


Figure 7.4 - Paired comparisons for sleep quantity when not on-call, stand-by and called-out

Study 1 identified that participants tend to get up at a similar time when on-call and when not on-call but also that participants tend to stay up later when callouts are expected. This could explain the lack of statistically significant differences between sleep indicators in the different on-call scenarios. Although expectation of receiving callouts was not recorded in the diary, sleep indicators when receiving callouts can be compared when calls are received whilst awake or when already asleep.

To test this, one-way ANOVAs were conducted between all sleep indicators whilst controlling for sleep condition (awake or asleep) at the time of receiving callouts were received.

As predicted, results show that when callouts took place whilst participants were still awake, participants went to bed on average later, fell asleep later, and had better sleep quality than when callouts occurred when already asleep. These results support hypothesis 31, hypothesis 30, and hypothesis 31 and are presented below in Table 7.7.

These results offer some support to the hypothesis that participants tend to stay awake until a time when they expect to be called-out as mentioned by interviewees.

However, it can also be that participants were simply dealing with callouts that kept them awake until later. Being disrupted when asleep, however, has a negative impact on sleep quality as could be expected from sleep research literature (Bonnet, 1989; Murray & Dodds, 2003).

Table 7.7 - Sleep factors when receiving callouts per sleep condition (asleep or awake). Sleep quality varies between 1 = "very good" and 5 = "very poor"

Factor		Awake	Asleep	ANOVA
Bed time	M	**23h 38min**	**22h 45min**	F(1,189) = 11.543**
	SD	07min	14min	
Up time	M	**6h 42min**	**6h 31min**	F(1,195) = 0.584
	SD	1h 27min	59min	
Sleep latency	M	**26 min**	**26 min**	F(1,189) = 0.011
	SD	21min	46 min	
Sleep quantity	M	**6h 40 min**	**6h 29 min**	F(1,189) = 0.743
	SD	1h 4 min	1h 32 min	
Sleep quality	M	**2.44**	**3.05**	F(1,191) = 8.183**
	SD	0.10	0.10	
Time asleep	M	**00h 39min**	**23h 12 min**	F(1,189) = 11.543**
	SD	7 min	14 min	

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

7.5.3.2 Anxiety, fatigue, mood (in the morning)

The results presented here for the scores of anxiety, fatigue, and mood collected in the morning represent the average score per participant for the seven days of data collected on-call and for the seven days of data collected when not on-call. This procedure is identical to the one used before when assessing the scores collected at the beginning of the on-call shift / end of the participants' *normal* working hours.

Table 7.8 below presents the results of the anxiety, mood, and fatigue scores for both the on-call and the not on-call week in the morning. To determine if on-call and not on-call scores were statistically different, paired T-tests were conducted. The results determined that the anxiety, fatigue, and mood scores given were statistically different during the on-call week in accordance with hypothesis 8, hypothesis 9, and hypothesis 10.

Table 7.8- Anxiety, fatigue, and mood when on-call and when not on-call (1 = Not anxious/fatigued at all, Very good mood; 5 = Very anxious/fatigued, Very bad mood)

Factor		Not on-call	On-call	T-test result
Anxiety morning	M	**1.53**	**1.95**	t(22) = 2.487*
	SD	0.66	0.80	
Fatigue morning	M	**1.95**	**2.54**	t(22) = 3.551**
	SD	0.63	0.88	
Mood morning	M	**1.73**	**2.15**	t(22) = 3.029**
	SD	0.76	0.89	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

Having found statistically significant differences between the scores when on-call and not on-call, to further explore these results comparisons between the two on-call scenarios and not being on-call were also conducted, i.e. being on *stand-by* and actually *receiving callouts*.

Table 7.9 below presents the results of the anxiety, mood, and fatigue scores for the stand-by data, the called-out data and the not on-call week. To explore the differences between these scores, three repeated measures ANOVAs with Greenhouse-Geisser correction were performed. Contrary to what was found regarding the scores at the end of a normal shift / start of an on-call shift no significant differences were found between the on-call scenarios and not on-call.

Table 7.9- Anxiety, fatigue, and mood when on-call and when not on-call (1 = Not anxious/fatigued at all, Very good mood; 5 = Very anxious/fatigued, Very bad mood)

Factor		Not on-call	Stand-by	Called	ANOVA
Anxiety morning	M	**1.73**	**2.03**	**1.96**	F(1.376, 19.268) = 0.366
	SD	0.18	0.21	0.28	
Fatigue morning	M	**2.14**	**2.44**	**2.45**	F(1.845, 25.823) = 1.414
	SD	0.67	0.88	1.12	
Mood morning	M	**1.95**	**2.29**	**2.23**	F(1.614, 22.569) = 1.529
	SD	0.82	1.02	1.22	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

7.5.3.3 End of normal working hours and the morning after

The scores for anxiety collected at the end of the normal working shift / start of on-call shift, and in the morning following the shifts were compared. In the event of statistically significant differences being found this would provide the first indication that events during the night would have an impact on the general well-being of participants. To assess the existence of differences between the scores, repeated measures t-tests were performed. The results of the tests indicated that no statistically significant differences are present between the scores collected at the beginning of the on-call shift and on the following morning for any of the factors either when on-call. These results are presented below in Table 7.10.

Table 7.10 - Anxiety, fatigue, and mood when on-call and when not on-call (1 = "not anxious/fatigued at all, very good mood"; 5 = "very anxious/fatigued, very bad mood")

		On-call		
Factor		**Evening**	**Morning**	**T-test result**
Anxiety	M	**1.98**	**1.92**	t(22) = 0.813
	SD	0.83	0.76	
Fatigue	M	**2.44**	**2.52**	t(25) = -1.005
	SD	0.71	0.85	
Mood	M	**2.22**	**2.11**	t(25) = 1.722
	SD	0.73	0.85	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

7.5.4 Multivariate tests

This section presents the multivariate tests conducted to continue testing the hypotheses presented at the beginning of the chapter. When statistically significant relationships have been found for the on-call data collected, or in the case of relevant hypothesis, these data have then been analysed for both on-call scenarios for which the data can be divided into. This allowed for the analysis of the influence of on-call scenario on the main results found regarding on-call data.

7.5.4.1 – At the beginning of the on-call shift and in the morning after

This section discussed the multivariate statistical tests used to test the hypothesis that relate to the relationships between the anxiety, fatigue, and mood scores collected both at the beginning of on-call shifts / end of *normal* working hours and in the morning after each shift. The scores used represent the weekly average (both for the on-call and the not on-call week) and each of the tests used is described in detail.

To test the hypotheses that sleep quality, sleep quantity and anxiety at the end of normal shift / start of an on-call shift when on stand-by will be significantly affected by experience (years working on-call) three linear regressions were planned (hypothesis 14, hypothesis 15, and hypothesis 16). Similarly to what was found in Study 2, the results were found to be non significant thus not supporting the hypotheses. Table 7.11 below presents these results.

Table 7.11 - Experience (years working on-call) with sleep quality, sleep quantity, and anxiety at the start of the on-call shift when on stand-by

	Anxiety beginning on-call shift		
Factor	**Beta**	**t-test**	**R^2**
Experience	**-0.050**	t(23) = -0.241	0.000
	Sleep quantity		
Experience	**0.155**	t(23) = 0.721	0.000
	Sleep quality		
Experience	**0.228**	t(23) = 1.124	0.000

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

A one-way ANOVA was also conducted to assess the hypotheses that anxiety at the end of normal shift / start of an on-call shift and sleep quality when on stand-by are significantly different between different age groups (hypothesis 17 and hypothesis 18). No relationship was found either for anxiety or sleep quality as shown below in Table 7.12.

Table 7.12 – Anxiety at the end of normal shift / start of an on-call shift and sleep quality per age group.

Factor		Under 25	25 to 34	35 to 44	45 to 56	Over 56	ANOVA
		Quality of sleep when not on-call per age group					
Quality of sleep	M	**-**	**2.46**	**2.23**	**2.52**	**2.42**	F(3,21) = 0.270
	SD	-	0.05	0.79	0.16	0.59	
		Anxiety when on stand-by per age group					
Anxiety	M	**-**	**1.86**	**1.86**	**1.61**	**2.15**	F(3,21) = 0.215
	SD	-	0.20	0.92	0.58	0.92	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To test the hypothesis that fatigue in the morning when on-call will be affected by anxiety at the end of normal shift / start of an on-call shift (hypothesis 19), a linear regression was performed. The results are presented below in Table 7.13 together with the results per on-call scenario and support the hypothesis. The on-call scenario analysis show that only being called-out actually leads to a significant positive relationship with in fatigue in the morning. It could be that, as put forward in Study 1, participants can, to a degree, predict which shifts will lead to callouts.

Table 7.13 – Linear Regression between fatigue in the morning (1= "not fatigued at all" to 5 = "very fatigued") and anxiety at the end of a normal shift / start of the on-call shift (1 = "not anxious at all" to 5 = "very anxious")

Factor	Beta	t-test	R^2
	Fatigue in the morning		
Anxiety beginning of **on-call** shift	**0.520**	t(21) = 2.983**	0.270
Anxiety beginning of **stand-by** shift	**0.437**	t(16) = 1.945	0.238
Anxiety beginning of **called-out** shift	**0.521**	t(16) = 2.439*	0.237

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To test the hypothesis that sleep quality when on-call will be affected by anxiety at the end of normal shift / start of an on-call shift (hypothesis 20), a linear regression was performed. The results are presented below in Table 7.14 together with the results per on-call scenario and support the hypothesis. No significant results were found on the on-call scenario analysis indicating that the relationship found when on-call is not due to one on-call scenario or the other.

Table 7.14 – Linear Regression between anxiety at the end of a normal shift / start of the on-call shift (1 = "not anxious at all" to 5 = "very anxious") and sleep quality (1 = "very good" to 5 = "very poor").

	Sleep quality		
Factor	**Beta**	**t-test**	**R^2**
Anxiety start of **on-call** shift	**0.395**	t(24) = 2.103*	0.156
Anxiety start of **stand-by** shift	**0.372**	t(16) = 1.921	0.139
Anxiety start of **called-out** shift	**0.316**	t(16) = 1.0353	0.063

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To test the hypothesis that fatigue in the morning when on-call will be affected by sleep quality (hypothesis 21), a linear regression was performed. The results are presented below in Table 7.15 together with the results per on-call scenario and support the hypothesis. The on-call scenario analysis also show that only sleep quality when being called out leads to a significant positive relationship with fatigue in the morning.

Table 7.15 - Linear regression between quality of sleep (1 = "very good" to 5 "very poor") and fatigue in the morning (1 = "not fatigued at all" to 5 = "very fatigued").

	Fatigue in the morning		
Factor	**Beta**	**t-test**	**R^2**
Sleep quality when **on-call**	**0.546**	t(24) = 3.195***	0.298
Sleep quality when on **stand-by**	**0.372**	t(16) = 2.043	0.207
Sleep quality when **called-out**	**0.499**	t(16) = 2.305*	0.202

* ρ<0.05

** ρ<0.01

*** ρ<0.001

Having verified the existence of a relationship between both anxiety and sleep quality and between anxiety and fatigue when on-call, initial support was found to test the hypothesis that sleep quality when on-call will mediate the effect of anxiety at the end of normal shift / start of an on-call shift on fatigue in the morning (hypothesis 22).

The mediation effect can be described as the effect by which one variable or factor accounts for the relationship between the predictor (independent variable or factor) and the criterion (dependent variable or factor) (Baron & Kenny, 1986). The path diagram replicated below in Figure 7.5, and firstly presented by Baron & Kenny, ilustrates the process of mediation.

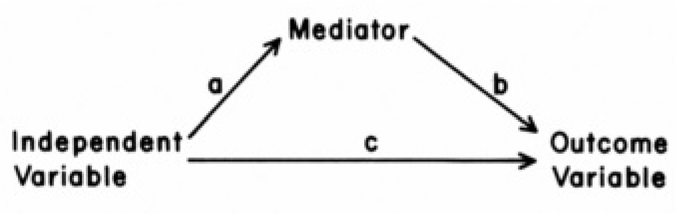


Figure 7.5- Mediation path diagram reproduced from Baron & Kenny, 1986

Moderation on the other hand, can be defined as "a qualitative (e.g., sex, race, class) or quantitative (e.g. level of reward) variable that affects the direction and/or strength of the relation between an independent or predictor variable and a dependent or criterion variable" (Baron & Kenny, 1986, p1174). The path diagram replicated below in Figure 7.6, and firstly presented by Baron & Kenny, ilustrates the process of moderation.

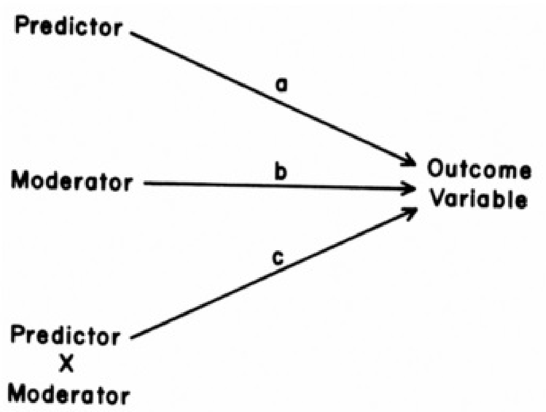


Figure 7.6 - Moderation path diagram reproduced from Baron & Kenny, 1986

The distinction between moderation and mediation can be thought of as "mediators explaining how external physical events take on internal psychological significance. Whereas moderator variables specify when certain effects will hold, mediators speak to how or why such effects occur. For example, choice may moderate the impact of incentive on attitude change induced by discrepant action, and this effect is in turn mediated by a dissonance arousal-reduction sequence " (Baron & Kenny, 1986).

Another way to think about the differences between moderation and mediation is that a moderating variable (or factor) is one that influences the strength of a relationship between any other two variables. A mediation variable (or factor) is a variable that explains the relationship between these two other variables or factors.

To assess the existence of such a mediation it is necessary to conduct a number of tests. Firstly, to test for "variations in levels of the independent variable significantly account for variations in the presumed mediator (i.e., Path a), then variations in the mediator significantly account for variations in the dependent variable (i.e., Path b), and finally, when paths a and b are controlled, a previously significant relationship between the independent and dependent variables is no longer significant with the strongest demonstration of mediation occurring when Path c is zero." (Baron & Kenny, 1986).

To do so "one should estimate the three following regression equations: first, regressing the mediator on the independent variable; second, regressing the dependent variable on the independent variable; and third, regressing the dependent variable on both the independent variable and on the mediator." (Baron & Kenny, 1986).

In the case of hypothesis 22, sleep quality is hypothesised to be the mediator variable, thus explaining the relationship between anxiety at the end of normal shift / start of the on-call shift and fatigue experienced in the morning after the shift. In accordance to the procedure described before the first test is to assess the relationship between the independent variable (anxiety at the beginning of the on-call shift) and the potential mediation variable (sleep quality) (Path a).

This test was already performed (hypothesis 20) where a relationship was identified. The results have been presented in detail before when discussing this hypothesis and are replicated below in Table 7.16.

Table 7.16 – Replication of hypothesis 20 results.

	Sleep quality		
Factor	**Beta**	**t-test**	**R^2**
Anxiety beginning of on-call shift	**0.395**	t(24) = 2.103*	0.156

* ρ<0.05

** ρ<0.01

*** ρ<0.001

The second test explores the relationship between anxiety at the beginning of on-call shift and fatigue in the morning (path c). Similarly to the previous test, this relationship has also already been assessed in hypothesis 19 and the results are replicated below in Table 7.17.

Table 7.17 - Replication of hypothesis 19 results

Fatigue in the morning

Factor	Beta	t-test	R^2
Anxiety beginning of on-call shift	**0.520**	t(21) = 2.983**	0.270

* ρ<0.05

** ρ<0.01

*** ρ<0.001

Lastly, it remains only to assess that, when controlling for paths a and b (anxiety and sleep quality, and sleep quality and fatigue), the relationship between anxiety at the end on a normal shift / beginning of on-call shift and fatigue in the morning is no longer significant (path c).

Results indicate that there is partial mediation in the relationship between anxiety at the end of a normal shift / beginning of an on-call shift and fatigue in the morning by sleep quality. A partial mediation is found as the relationship between the independent variable and the dependent variable (path c) was solely reduced instead of made non-significant. Partial mediations are not uncommon in the social sciences where several variables tend to be at play in any given relationship. Table 7.18 below presents these results.

Table 7.18 - Mediation results for path (c) whilst controlling path (b)

Fatigue in the morning

Factor	Beta	t-test
Sleep quality when on-call (path b)	0.404	T(23) = 2.314*
Anxiety beginning of on-call shift (hypothesis 8)	**0.520**	t(23) = 2.983**
Anxiety beginning of on-call shift (path c)	**0.361**	t(23) = 2.066*
R^2	0.408	

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To test the significance of the mediation, a Sobel test was calculated which found no significant mediation effect (ρ = n.s). With small samples a bootstrap analysis is, however, recommended due to the assumption of the shape of the sampling distribution of the indirect effect of the Sobel test (Preacher & Hayes, 2004). The bootstrap confidence intervals were, therefore, calculated but here also a non significant mediation effect was found. The lack of statistical significance of the bootstrap analysis indicates that no evidence was found to support the hypothesis that the relationship between anxiety at the beginning of on-call shift and fatigue in the next morning is mediated by sleep quality.

To test the hypothesis that fatigue in the morning when on-call will be affected by sleep quantity a linear regression was performed (hypothesis 23). The results are presented below in Table 7.19 together with the results per on-call scenario, and support the hypothesis. The on-call scenario analysis also shows that only being called-out actually leads to a significant positive relationship with fatigue in the morning.

Table 7.19 - Linear Regression fatigue in the morning when on-call (1 = "not fatigued at all" to 5 = "very fatigued") and sleep quantity in hours and minutes.

Fatigue in the morning			
Factor	**Beta**	**t-test**	**R^2**
Sleep quantity when **on-call**	**-0.559**	t(24) = -3.300***	0.283
Sleep quantity when on **stand-by**	**-0.099**	t(15) = - 0.372	0.010
Sleep quantity when **called-out**	**-0.577**	t(15) = - 2.735*	0.288

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To test the hypothesis that sleep latency when on-call will be affected by anxiety at the end of normal shift / start of an on-call shift (hypothesis 24) a linear regression was performed. The results, presented below in Table 7.20 did not support the hypothesis.

Table 7.20 - Linear regression and anxiety at the end of a normal shift / start of the on-call shift (1 = "not anxious at all" to 5 = "very anxious") and sleep latency in hours and minutes.

	Sleep latency		
Factor	**Beta**	**t-test**	$\mathbf{R^2}$
Anxiety at the beginning of on-call shift	**0.209**	t(24) = 1.049	0.044

* ρ<0.05

** ρ<0.01

*** ρ<0.001

7.5.4.2 Calls

This section starts by discussing the multivariate statistical tests used to test the hypotheses that relate to the relationships between call specific factors. The section then goes on to describe the tests performed to investigate the hypotheses that associate both call specific factors and the anxiety, fatigue, and mood scores collected both at the beginning of the on-call shift / end of *normal* hours of work and in the morning after on-call shifts.

To test the hypotheses that amount of time required to get back to sleep after a callout when on-call is affected by the length of callouts (hypothesis 25) and that amount of time required to fall back asleep after a call out is statistically affected by time of day (or night) (hypothesis 32) a multiple linear regression was conducted. Both the data collected for the on-call and the not on-call week were used together, as during the not on-call week only three callouts were received by participants whilst already asleep, which constitutes too few data points to be able to allow for comparison between the two weeks (on-call and not on-call). Table 7.21 presents the results which show that the longer the length of the callout, the longer the time required to get back to sleep.

Table 7.21 - Linear Regression length of callout and time to get back to sleep

	Time to get back to sleep (BTS)		
Factor	**Beta**	**t-test**	**R^2**
Length of callout	**0.385**	t(37) = 2.435*	0.148
Time of day (in hours)	**0.163**	t(35) = 0.964	0.027

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To test the hypotheses that quality of sleep when on-call and receiving callouts is significantly different between short callouts (10min or less) and longer callouts and that mood in the morning when on-call and receiving callouts is significantly different between short callouts (10min or less) and longer callouts (hypothesis 26 and hypothesis 27), two one-way ANOVAs were performed. Table 7.22 below presents the results which show statistically significant differences between length of callouts and quality of sleep. No relationship was, however, identified for mood.

Table 7.22 - Sleep quality ((1 = "very good" to 5 = "very poor") and mood ((1 = Very good mood; 5 = Very bad mood) in the morning per length of callout

		Length of callout		
Factor		**<10min**	**>10min**	**ANOVA**
Sleep quality	M	**2.44**	**2.85**	
	SD	1.2	1.26	F(1,189) = 4.832*
Mood in the morning	M	**2.35**	**2.50**	
	SD	1.32	1.25	F(1,189) = 0.627

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To test the hypotheses that ability to perform duties (performance) is statistically different between callouts received whilst awake or asleep and that sleep quality is statistically different between callouts received whilst awake or asleep, two one-way ANOVAs were performed (hypothesis 28 and hypothesis 29).The tests were conducted for all calls received both during the on-call week and during the not on-call week.

Table 7.23 below presents the results which support the hypotheses.

Table 7.23 – Ability to perform duties (1 = "very able" to 5 = "not able at all") and quality of sleep (1 = Very good quality of sleep, 5 = Very poor quality of sleep) when asleep or awake at the time of the call.

		Callout asleep		
Factor		**No**	**Yes**	**ANOVA**
Ability (performance)	M	**1.95**	**2.39**	
	SD	1.13	0.99	($F(1,190) = 5.244$*)
Sleep quality	M	**2.44**	**3.05**	
	SD	1.22	1.19	($F(1,190) = 8.183$**)

* $\rho<0.05$

** $\rho<0.01$

*** $\rho<0.001$

To assess the hypothesis that a sleep fragmentation rate of around 20 minutes would be more detrimental to performance, a linear regression was planned (hypothesis 33).

Unfortunately, the number of respondents that received more than one call per night when already asleep was very low. Moreover, only 42 callouts (of the total 204) were received during the participants' sleep. As a result this analysis could not be performed as the average number of callouts when asleep per participant per night was 0.12 calls.

To test the hypotheses that fatigue in the morning when on-call is statistically affected by number of callouts (hypothesis 34) anxiety in the morning when on-call is statistically affected by number of callouts (hypothesis 35), and mood in the morning when on-call is statistically affected by number of callouts (hypothesis 36) three linear regressions were performed.

Table 7.24 below presents the results of these tests and show that only fatigue was found to be correlated with the number of callouts.

Table 7.24 Fatigue, anxiety, and mood (1 = Not anxious/fatigued at all, Very good mood; 5 = Very anxious/fatigued, Very bad mood) in the morning with number of callouts

Fatigue in the morning

Factor	Beta	t-test	R^2
Number of callouts	**0.470**	t(16) = 2.132*	0.172

Anxiety in the morning

Factor	Beta	t-test	R^2
Number of callouts	**-0.103**	t(16) = -0.416	0.011

Mood in the morning

Factor	Beta	t-test	R^2
Number of callouts	**0.076**	t(16) = 0.303	0.006

* ρ<0.05

** ρ<0.01

*** ρ<0.001

To investigate the hypothesis that fatigue in the morning when on-call is statistically affected by time of day callouts occur (hypothesis 37), the average timing of calls would have to be calculated as the independent variable in the model. However, due to the large variation (SD ≈ 7h) in the timing of calls, the mean would not be a strong measure to conduct the analysis. As a result the tests could not be performed. Another alternative was to use the full data set for the calls where the timing of each call can be used in the analysis. This however causes even larger problems as each participant received several calls during their on-call shift but only provided one fatigue score during the next day. This means that regardless of the number of callouts participants received during an on-call shift there is only one fatigue score associated with that shift. This would bias the model to non significant.

A more indicative measure found to be of significance by sleep research, and one that was mentioned by a larger number of participants in Study 2, is the timing of the call in relation to the amount of sleep: fatigue in the morning when on-call is statistically affected by amount of time after going to sleep that callouts occur (hypothesis 38).

A linear regression was performed to test the hypothesis. Table 7.25 below presents the results which do not support the hypothesis.

Table 7.25 - Fatigue in the morning (1 = Not fatigued at all, 5 = Very fatigued) per time of callout after having gone to sleep

Fatigue in the morning			
Factor	**Beta**	**t-test**	**R^2**
Time after going to sleep that callouts occur	**-0.156**	t(39) = -0.989	0.024

* ρ<0.05

** ρ<0.01

*** ρ<0.001

7.5 Discussion

The results of this study mainly support the findings of Study 1 and Study 2. Nonetheless, there were a number of hypotheses that were not verified. Table 7.26 shown below shows a summary of the results of the hypotheses of this study.

Table 7.26 - Summary of hypothesis testing

Number	Hypothesis	Support (Y/N)	Test	Result
Hypothesis 1	sleep quantity will be significantly different in the on-call week and in the non on-call week	N	$t(20) = 5.030$, p = n.s	No results found
Hypothesis 2	sleep quantity will be significantly different between receiving callouts and stand-by and not being on-call	Y	$F(1.756, 26.341) = 4.177$, $p<0.05$	Sleep quantity when receiving callouts in significantly different from sleep quantity when not on-call
Hypothesis 3	sleep quality will be significantly different in the on-call week and in the non on-call week	Y	$t(22) = 2.586$, $p<0.05$	Sleep quality when on-call is significantly worse than when not on-call
Hypothesis 4	sleep latency will be significantly different in the on-call week and in the non on-call week	N	$t(22) = 1.212$, p = n.s	No results found
Hypothesis 5	anxiety at the end of normal shift / start of an on-call shift will be significantly different in the on-call week and the non on-call shift week	Y	$t(22) = 4.606$, $p<0.001$	Anxiety at the end of normal shift / start of an on-call shift when on-call significantly worse than when not on-call
Hypothesis 6	fatigue at the end of normal shift / start of an on-call shift will be significantly different in the on-call week and the non on-call week	Y	$t(22) = 3.038$, $p<0.01$	Fatigue at the end of normal shift / start of an on-call shift when on-call significantly worse than when not on-call
Hypothesis 7	mood at the end of normal shift / start of an on-call shift will be significantly different in the on-call week and the non on-call week	Y	$t(22) = 5.030$, $p<0.001$	Mood at the end of normal shift / start of an on-call shift when on-call significantly worse than when not on-call
Hypothesis 8	anxiety in the morning will be significantly different in the on-call week and the non on-call shift week	Y	$t(22) = 2.487$, $p<0.05$	Anxiety in the morning when on-call significantly worse than when not on-call
Hypothesis 9	fatigue in the morning will be significantly different in the on-call week and the non on-call week	Y	$t(22) = 3.551$, $p<0.01$	Fatigue in the morning when on-call significantly worse than when not on-call
Hypothesis 10	mood in the morning will be significantly different in the on-call week and the non on-call week	Y	$t(22) = 3.029$, $p<0.01$	Mood in the morning when on-call significantly worse than when not on-call
Hypothesis 11	callouts will occur both during the on-call week and the non on-call week	Y	-	66 callouts occurred during the not on-call week
Hypothesis 12	fatigue end of normal shift / start of an on-call shift when on-call will be significantly different between the days of the on-call week	N	$F(4.441, 84.380) = 1.152$, p = n.s	No results found
Hypothesis 13	anxiety end of normal shift / start of an on-call shift when on-call will be significantly different between	Y	$F(3.880, 77.594) = 3.082$, $p<0.05$	Reduction in anxiety at the end of the on-call week

	the first six days and the last day of the on-call week			
Hypothesis 14	anxiety at the end of normal shift / start of an on-call shift when on stand-by will be significantly affected by experience (years working on-call)	N	$\beta = -0.050$, $t(23) = -0.241$, p = n.s	No results found
Hypothesis 15	sleep quality when on stand-by will be significantly affected by experience (years working on-call)	N	$\beta = 0.155$, $t(23) = 0.721$, p = n.s	No results found
Hypothesis 16	sleep quantity when receiving callouts will be significantly affected by experience (years working on-call)	N	$\beta = 0.228$, $t(23) = 1.124$, p = n.s	No results found
Hypothesis 17	anxiety at the end of normal shift / start of an on-call shift when on stand-by will be significantly different between different age groups	N	$F(3,21) = 0.270$, p = n.s	No results found
Hypothesis 18	sleep quality when on stand-by will be significantly different between different age groups	N	$F(3,21) = 0.215$, p = n.s	No results found
Hypothesis 19	fatigue in the morning when on-call will be affected by anxiety at the end of normal shift / start of an on-call shift	Y	$\beta = 0.520$, $t(21) = 2.983$, $p<0.01$	The higher anxiety in the evening the higher fatigue in the morning
Hypothesis 20	sleep quality when on-call will be affected by anxiety at the end of normal shift / start of an on-call shift	Y	$\beta = 0.395$, $t(24) = 2.103$, $p<0.05$	The higher the anxiety in the evening the worse the quality of sleep
Hypothesis 21	fatigue in the morning when on-call will be affected by sleep quality	Y	$\beta = 0.298$, $t(24) = 3.195$, $p<0.001$	The lower the impact on sleep quality the lower the fatigue in the morning
Hypothesis 22	sleep quality when on-call will mediate the effect of anxiety at the end of normal shift / start of an on-call shift on fatigue in the morning	N	Sobel test = n.s.	No results found
Hypothesis 23	fatigue in the morning when on-call will be affected by sleep quantity	Y	$\beta = -0559$, $t(24) = -3.300$, $p<0.001$	The higher the sleep quantity the lower the fatigue in the morning. On-call scenario analysis reveals that receiving callouts is the key scenario.
Hypothesis 24	sleep latency when on-call will be affected by anxiety at the end of normal shift / start of an on-call shift	N	$\beta = 0.209$, $t(24) = 1.049$, p = n.s	No results found
Hypothesis 25	amount of time required to get back to sleep after a callout when on-call is affected by the length of callouts	Y	$\beta = 0.385$, $t(37) = 2.435$, $p<0.05$	The longer the callout the longer the amount of time required to get back to sleep

Hypothesis 26	quality of sleep when on-call and receiving callouts is significantly different between short callouts (10min or less) and longer callouts	Y	F(1,189) = 4.832, $p<0.05$	Sleep quality when on-call and receiving callouts is significantly better when callouts are shorter than 10 minutes when compared with longer calls.
Hypothesis 27	mood in the morning when on-call and receiving callouts is significantly different between short callouts (10min or less) and longer callouts	N	F(1,189) = 0.627, p = n.s	No results found
Hypothesis 28	ability to perform duties (performance) is statistically different between callouts received whilst awake or asleep	Y	(F(1,190) = 8.183, $p<0.01$	Ability is more affected when callouts occur when participants already asleep
Hypothesis 29	sleep quality is statistically different between callouts received whilst awake or asleep	Y	(F(1,190) = 5.244, $p<0.05$	Sleep quality is more affected when callouts occur when participants already asleep
Hypothesis 30	time asleep is statistically different between callouts received whilst awake or asleep	Y	F(1,189) = 11.543, $p<0.01$	Participants go to sleep later when callouts occur whilst they are still awake
Hypothesis 31	bed time is statistically different between callouts received whilst awake or asleep	Y	F(1,189) = 11.543, $p<0.01$	Participants go to bed later when callouts occur whilst they are still awake
Hypothesis 32	amount of time required to fall back asleep after a call out is statistically affected by time of day (or night)	N	β = 0.163, t(35) = 0.964, p = n.s	No results found
Hypothesis 33	ability to perform duties (performance) is significantly different for different sleep fragmentation rates	N	Insufficient cases to test	No results found.
Hypothesis 34	fatigue in the morning when on-call is statistically affected by number of callouts	Y	β = 0.470, t(16) = 2.132, $p<0.05$	The higher the number of callouts the higher the fatigue in the morning
Hypothesis 35	anxiety in the morning when on-call is statistically affected by number of callouts	N	β = -0.103, t(16) = -0.416, p = n.s	No results found.
Hypothesis 36	mood in the morning when on-call is statistically affected by number of callouts	N	β = 0.076, t(16) = 0.303, p = n.s	No results found.
Hypothesis 37	fatigue in the morning when on-call is statistically affected by time of day callouts occur	N	Insufficient cases to test	No results found.
Hypothesis 38	fatigue in the morning when on-call is statistically affected by amount of time after going to sleep that callouts occur	N	β = -0.156, t(39) = -0.989, p = n.s	No results found.

7.5.1 On-call versus not on-call (hypothesis 1 to hypothesis 11)

As expected from the findings of Study 1, callouts were found to occur both during the on-call week and the non on-call week.

Similarly expected were the results found for anxiety, fatigue, and mood scores both at the end of the *normal* working hours / beginning of on-call shift and in the morning which were all found to be significantly different between the on-call week and the not on-call week. This is in accordance with other on-call research where on-call work has been found to affect these factors (e.g. Nicol & Botterill, 2004; Torsvall & Akerstedt, 1988; Wesnes et al., 1997), and in shiftwork research (Dorrian et al., 2011; M. Harma et al., 2002b; Mikael Sallinen & Kecklund, 2010).

Contrary to expectations, sleep quantity was not found to vary significantly between the on-call week and the non on-call week. Sleep quality, however, was. It could be that sleep quantity, as described by interviewees in Study 1 is closed linked to the reception of callouts whilst sleep quality is potentially more closely linked to anxiety before going to sleep. In effect, when separating the on-call week to on-call scenarios sleep quantity scores supports this as sleep quantity was found to be reduced when receiving callouts when compared to not being on-call. This is a result which is aligned with sleep research where sleep disruption and sleep fragmentation have been shown to reduce both sleep quantity and quality (e.g. Ekstedt et al., 2009; Lim et al., 2012; Martin et al., 1996; Stepanski et al., 1984; Stepanski, 2002). Similarly, sleep research also indicates that repetitive sleep disruption leading to sleep deprivation (as is the case when working seven consecutive days on-call) has a negative impact on sleep. In the same way, sleep quality was not found to vary when the on-call week was separated into on-call scenarios, also supporting the hypothesis that anxiety when on-call is potentially influenced by anxiety and not the reception of callouts (respondents would not know which scenario they would be in on each night).

7.5.2 Cumulative (hypothesis 12 to hypothesis 18)

Anxiety scores, as expected, were found to differ between the first six days of the on-call week and the last on-call day indicating that the conclusion of the on-call week relieves anxiety. This conforms with the findings of Study 1 where participants reported feeling relieved at the end of the on-call week. The non significance of a cumulative effect regarding the fatigue scores however was not expected. Cumulative fatigue is a well-known effect in sleep research which originates in the accumulation of sleep debt or extended wakefulness through a number of days (Doi et al., 2003; Jay et al., 2008; Van Dongen, Maislin, et al., 2003). It could be due to daily recordings of fatigue being recorded independently of receiving a callout or not which would affect fatigue through sleep disruption causing reduced sleep quantity. The anxiety scores, on the other hand, simply relate to being on-call or not and thus are not influenced by the reception of callouts.

Experience and age were mentioned by interviewees in Study 1 as factors of relevance for on-call work. Interviewees believe that on-call work is harder for older workers but that experience helps to deal with the anxiety of being on-call. Shiftwork research has found some support to these assertions where an effect from experience on performance has been found (Gillberg et al., 2003). Similarly there is evidence that older shiftworkers can find it harder to work shifts (e.g. Costa & Di Milia, 2008; Mikko Harma, 1996; Pires et al., 2009) and that sleep quality is on the key factors involved. Study 2, however, found no significant effects for either experience or age nor did this study, where no supporting evidence for these effects on sleep quality and quantity or anxiety when on stand-by and receiving call-outs was found. Circadian disruption has been pointed out as the key process at play with regards to age where older workers have greater difficulty in re-synchronising after circadian disruption (Ribet & Derriennic, 1999; Rouch et al., 2005). It may be that, if the number of calls that disturb sleep are quite low, the sleep drive overcomes the effects of age on sleep quality and quantity (e.g. Akerstedt, 1988; Billiard & Dauvilliers, 2004; Comperatore & Krueger, 1990; Nesthus et al., 2001; Turek, 1986).

7.5.3 Anxiety and Sleep (hypothesis 19 to hypothesis 24)

As hypothesised, anxiety at the end of a normal shift was found to affect both sleep quality and fatigue in the morning, which is in alignment with sleep research and shiftwork research. This research has consistently found that stress affects both sleep and fatigue (e.g. Dinges, Neri, & Rosekind, 1997; Hall, Francis II, Hammerschimidt, Goglia, & Black, 1999). Similarly, as hypothesised, fatigue in the morning was found to be affected both by sleep quality and quantity.

The relationship between anxiety and reduced sleep quality leading to increased fatigue has also been found in on-call research. This is both due to the anticipation of a callout and the sleep disruption itself (Imbernon et al., 1993; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988). Similarly to shiftwork research, sleep research has also consistently found that stress (and anxiety as a subset of stress) is associated with fatigue and reduced sleep quality (Ǻkerstedt et al., 2004; Dahlgren et al., 2005; Janssen & Nijhuis, 2004; Thorsteinsson & Brown, 2009).

Unfortunately no support was found for the role of sleep quality as the mediator of the relationship between anxiety and fatigue. This relationship has been identified by other research which has found that a higher number of stressful life events led to higher levels of fatigue and that this relationship was mediated by low quality of sleep (Thorsteinsson & Brown, 2009). Working hours research, however, has yet to clearly identify a similar relationship. A review of stress related research has concluded that stress is associated with shortened sleep, sleep fragmentation, and a potential reduction of the deep sleep stages (Ǻkerstedt, 2006b). All these have also been associated with fatigue and sleep quality and all are inherent effects of on-call work. So although no significant results were identified in this thesis regarding the mediation effect of sleep quality on the relationship between anxiety and fatigue, it is still expected that this relationship exists. It is possible that the sample size in this study was not large enough to identify a statistically significant result and that future studies will find support for this relationship.

Contrary to the effects found for fatigue and sleep quality, no effect was found between anxiety at the start on an on-call shift and sleep latency as predicted by interviewees in Study 1. It appears that anxiety has no effect on the amount of time required to fall asleep or it could simply be that other factors such as fatigue, or the homeostatic sleep drive process overcomes any effect that anxiety might have (e.g. Borbély, 1982; Costa, 2003; Kong, 2008). Once more, it could simply be that the small sample of this study did not allow for significant values to emerge as all sleep indicators measured varied considerably.

7.5.4 Callouts (hypothesis 25 to hypothesis 38)

Results show that the majority of calls occur between 16h00 and midnight (49.0% of all calls) and the next peak is seen in calls taking place between 06h01 and 08h00 (10.3% of all calls). These results suggest that there might be an attempt to not disturb on-call staff between 00h00 and 06h00 or it might simply be that most calls are related either to issues with the beginning or end of the night shift. The day shift usually starts at 06.00 and the night shift at 23.00. That most calls were received when the participants were still awake offers the explanation for the timings of callouts. Possession work represents the majority of the work conducted in the railways. A possession is the disconnecting of a section of track form the network so that maintenance work or network upgrades can be conducted on that section. It is a process that involves a large amount of planning and communication between several functions and, as such, is bound to incur a number of issues. Possessions are usually taken right after the last train (around 00h) and terminate before the first morning train (around 05h). This explanation is further supported by the finding that the majority of calls take place when the participants are still awake, indicating that participants were staying up late, possibly waiting for possessions to be taken and, as such, minimising the chances of being disrupted whilst asleep. These findings are further supported by Study 1, where possessions were identified as one of the main reasons to be called-out.

The large variation in the number of calls per participant indicate that some participants have much more intense on-call work than others. The fact that the data was collected on different weeks however could simply mean that other factors, e.g. weather, could be the cause of the variation.

Based on sleep inertia research it was predicted, and verified, that longer calls would lead to longer amounts of time required to get back to sleep (Balkin & Badia, 1988; David Dinges et al., 1997; Miccoli et al., 2008). It is thought that these would allow participants to break through the sleep inertia bringing them to a point in which it would be difficult to fall back to sleep. Circadian disruption is one of the key factors leading to sleep inertia and so is awaking from deeper stages of sleep (e.g. Borbély, 1982; Van Dongen, 2006). Deep sleep forced awakening has been linked to both sleep inertia, reduced sleep quality and fatigue (Balkin & Badia, 1988; Miccoli et al., 2008).

Similarly, it was expected that both sleep quality and mood would also be affected by the length of call-outs. Significant results were found for sleep quality but not regarding mood. As stated above both sleep inertia and circadian sleep research have found similar effects on sleep quality arising from sleep disruption. As predicted by interviewees in Study 1, short calls (under 10min) were found to be less disruptive than longer calls. This too is in accordance with sleep inertia research which has found that a period of time is required to actually overcome the homeostatic sleep drive and that in the absence of major sleep deprivation, it rarely exceeds 30 minutes and that falling back asleep after this is difficult (Hofer-Tinguely et al., 2005; Jewett et al., 1999; Tassi & Muzet, 2000).

On the other hand no significant effects were found for mood, although such a relationship has been found both by sleep research and on-call research. Both of these areas have identified that disruption affects mood but have not hypothesised that a connection might exist between mood and the length of the disruption. In effect, the same sleep stage effect might be present here where mood could be affected by disruption to the deeper stages of sleep. (Edéll-Gustafsson, 2002; Hofer-Tinguely et al., 2005; Van Dongen, Maislin, et al., 2003).

Similarly, no relationship was found between the amount of time required to fall asleep and the timing of calls or with the number of calls received. Results show that the amount of time required to fall asleep is identical for all hours of the day, and for any number of calls. Here also, it may be that sleep stage is the key factor at play (Van Dongen, Maislin, et al., 2003), with sleep disruption research having solely focussed on the rate of the disruption and not the length (Lim et al., 2012; Martin et al., 1996; Phillipson et al., 1980).

Also based on sleep inertia research (e.g. Tassi & Muzet, 2000) together with sleep disruption research (e.g. Bonnet & Arand, 2003), it was expected that the ability to perform on-call duties would be significantly more impaired when asleep and receiving callouts than when callouts are received whilst still awake. Similarly, sleep quality was also expected to be more affected when callouts were received when asleep than when still awake. As hypothesised, both ability to perform and sleep quality were found to be more affected when participants were already asleep than when awake. Both sleep inertia and sleep disruption research have found that both performance and sleep quality are affected by sleep disruption (Balkin & Badia, 1988; Lim et al., 2012; Miccoli et al., 2008). In the same lines, both bed time and time asleep were hypothesised to be delayed when callouts occurred whilst participants were still awake at the time of the first callout. This is in line with findings from Study 1 where it was found that participants tend to get up at a similar time when on-call and not on-call but also that participants tend to stay up later when callouts are expected. The significant results found offer support to this hypothesis.

Circadian rhythms research has identified that wakefulness and performance are at its lowest and sleepiness and the risk of accidents are at their maximum in the early hours of the morning (e.g. McGuffog, Turner, & Stone, 2004; Spencer et al., 2006). On-call research has found that working on-call can lead to impaired cognitive performance (Saxena & George, 2005; Wesnes et al., 1997). Sleep disruption research has also identified that a sleep fragmentation rate of around 20 minutes leads to the highest impact on performance (Bonnet & Arand, 2003). It was, therefore expected that such a callout rate would lead to similar findings but sadly there were not enough cases to allow for testing of sleep fragmentation rates.

When assessing the level of impact callouts have on the levels of fatigue, anxiety, and mood on the morning following on-call shifts, it was expected that the higher the disruption (number of calls), the greater the impact, especially on fatigue. This was indeed verified, with the higher the number of callouts received when on-call, the higher the fatigue experienced the morning after. A similar relationship, however, was not identified for anxiety or mood, with the number of calls not being identified as an influencing factor for either. Fatigue levels are known to be directly dependent on amount of sleep, which in turn is affected by sleep disruption (e.g. Dawson & Mcculloch, 2005; Åkerstedt & Wright, 2009). Anxiety and mood, although known to also be affected, do not have such a direct relationship with the number of calls (e.g. Kiernan, Civetta, Bartus, & Walsh, 2006). Sleep research for example has found a clear relationship between sleep fragmentation and increased fatigue (e.g. Bonnet & Arand, 2003; Levine, Roehrs, Stepanski, Zorick, & Roth, 1987; Stepanski, 2002), which seems also to be related to sleep stages, where disruption to deeper stages of sleep is more damaging to both the quality of sleep and the ability to fall back asleep (e.g. Kerkhof & Van Dongen, 2010; Pinel, 1992). This could also be a factor of influence here.

Sleep stage was not one of the factors assessed in this study (or indeed in this thesis) but 'time of day callouts occur' and the 'amount of time these occur after going to sleep' were. It was expected that time of callout would affect fatigue in the morning as described by interviewees in Study 1 and again in Study 2 although no consensus on the most damaging time could be identified. Sadly, there were not enough callouts during the weeks assessed to test the former and no significant results were found regarding the latter. It could simply be that the lack of significant results was due to the low number of callouts received which limits the power of the analysis. As these tests show, on-call work is a complex phenomenon that cannot be understood simply.

7.6 Framework iteration

The findings of this study allowed specific callout characteristics to be tested and integrated into the previous version of the framework. In particular, the effect of timing, duration, and length of callouts was explored and their relationship with fatigue, mood, and anxiety tested. The findings mainly support the findings of Study 1, where participants stated that the higher the volume of calls, the higher the disruption and the higher the fatigue that ensued from it. Callouts were found to have an impact mainly on fatigue, with anxiety and mood not being found to be affected. This study also found further support for the relationships identified both in Studies 1 & 2, and from literature (e.g. performance) and these results are maintained in the framework. There were also a number of relationships identified previously in Study1, Study 2 and other on-call literature that this study did not support (e.g. duration of callouts and negative outcomes). These relationships were nonetheless maintained in the framework. This was done due to the recognition that the amount of research onto on-call work is limited, and that the studies conducted for this thesis suffer from a number of limitations. Having found such relationships in one study and not on the other indicated to the researcher the need for more detailed research. In the meantime, however, allowing these factors to remain in the framework will create greater awareness of them and will lead other research to explore them in greater detail. Figure 7.7 - Iterated framework shows the updated framework, where the findings from this study are highlighted in green. The implications of this framework for the understanding of on-call work in rail maintenance, and beyond, will be examined in greater depth in the next chapter.

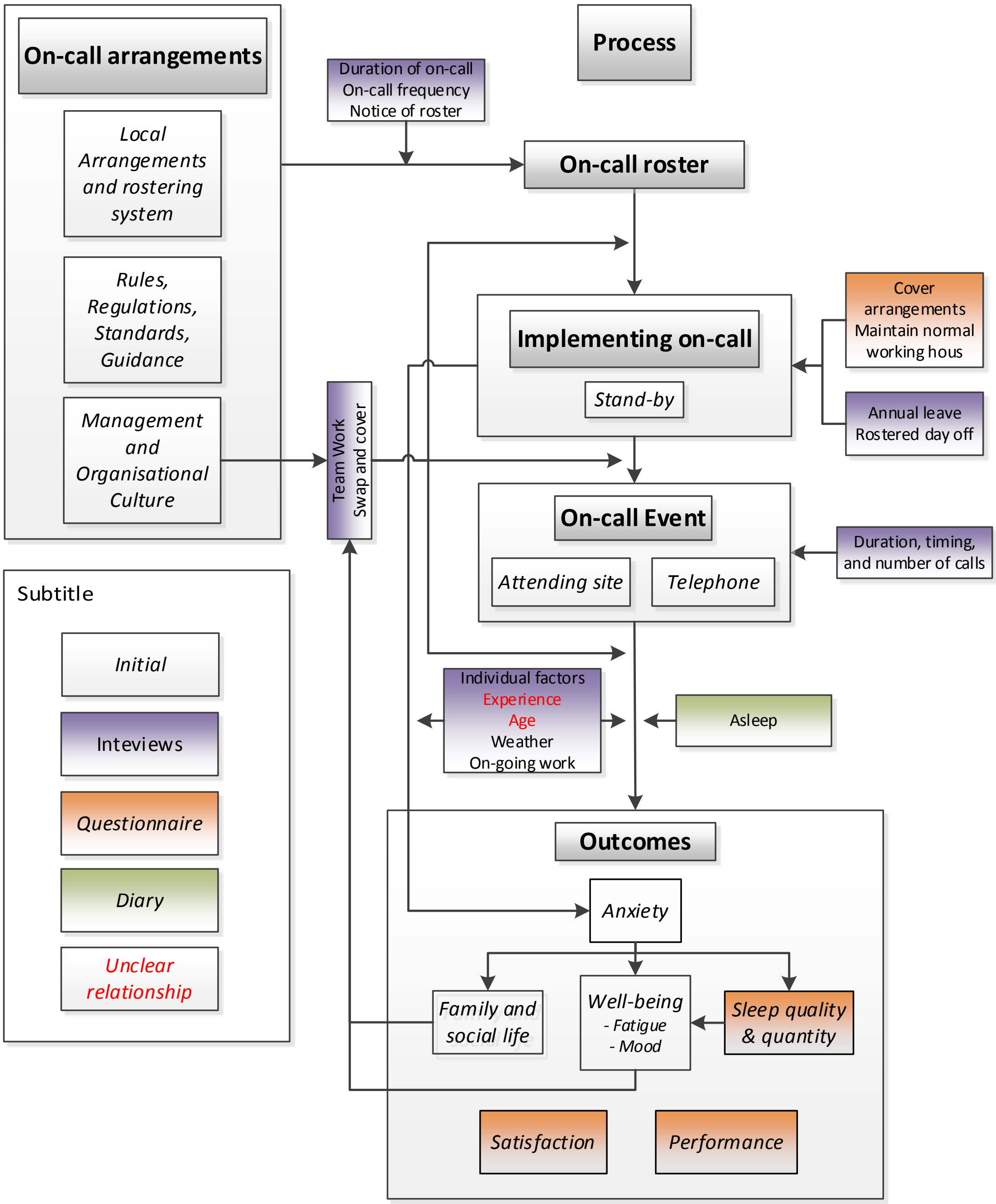


Figure 7.7 - Iterated framework

7.7 Methodological implications

The three studies of this thesis, through the usage of three different methods, allowed a good overview of the on-call scheduling system of work. Further, the three studies showed mainly consistent findings across the different factors investigated offering further support to the relationships indicated in literature and those indicated in Study 1 and Study 2. Nonetheless, discrepancies were also found between the three studies (e.g. the impact of timing of callouts). These discrepancies between the verbal reports of Study 1, the survey data of Study 2, and that the real-time reports of Study 3 indicate that there is still much to be learned about on-call work.

There are a number of probable alternatives that can justify the disparate results of Study 3 with those of Studies 1 and 2; the way the data was collected, the way the data was aggregated, or simply due to the small number of participants in this study. It might also be that the data collected from Studies 1 and 2 were influenced by re-collection bias and that the results of Study 3 are actually more accurate. This is unlikely, as other research has clearly identified a large number of negative outcomes associated with stress, sleep disruption, and reduced sleep quantity and quality (e.g Bonnet & Arand, 2003; Pilcher & Coplens, 2000; Van Dongen et al., 2003).

The small number of callouts received by participants in Study 3 could indicate that callouts are not as frequent as on-call staff believe they are. It can also be that the weeks observed were below average quiet weeks or that the participants involved in the study are not those most affected by on-call on average. It is also important to remember that many of the scores collected and analysed on all three studies represent perceived scores that are vulnerable to biases, misjudgements or just plain deception (e.g. in response to performance).

It seems clear that the on-call scheduling system of work has specific idiosyncrasies that require further research to determine how the different factors interact. Future work could, for example, collect anxiety, fatigue, and mood scores at the time of each callout. This would allow for a better assessment of the impact of timing and length of each callout. Specific callout data can also be used to identify the consequences arising from the content of callouts.

7.8 Chapter Conclusion

The results of the third and final study conducted for this thesis have found support for some of the relationships put forward by Study 1 and supported by Study 2 (e.g. anxiety leads to lower sleep quality). This study, however, has also found contradictory findings to those of Studies 1 and 2 (e.g. no cumulative effect of fatigue during the on-call week). This shows that there is still much work that needs to be conducted into the idiosyncrasies of on-call work and into the relationships between the many factors present in this scheduling system of work. The fact that this system of work is not operated by itself but is executed in parallel with other systems (e.g. shiftwork), nonetheless, makes it a very difficult topic to address and isolate.

The organisation of on-call work around the three different on-call scenarios identified in Study 1 was, in some instances, not supported by the results of Study 3, where few differences were found between the two on-call scenarios tested (stand-by, and receiving calls). In other instances, however, receiving callouts was identified as the scenario with the stronger impact due to direct disruption. Moreover, there are fundamental differences between solely being on stand-by and being called out. This has greater importance because the number of participants who also reported receiving callouts when not technically on-call is substantial. Although the impact of being on stand-by was not generally found to be as large as anticipated, this study made it clear that on-call work when receiving callouts leads to direct impacts on sleep quality and fatigue.

These findings were then integrated into the framework produced. The presented framework represents the final findings of this thesis and, although, not a final model in itself, can and should be used both by industry and researchers as an initial platform to analyse on-call work. Further work should aim to further investigate the factors discussed in this chapter with a larger call sample, in the attempt to explore in greater detail the influence of timing, length, and number of calls.

The next chapter will present the general discussion for this thesis and explores both the strengths and the limitations of the work conducted. The chapter will start by presenting the main findings of all three studies conducted and will proceed to draw a general picture of the on-call scheduling system of work and reflection on the existing literature and guidance in light of these findings. The chapter will then draw on these findings and present a list of on-call work management recommendations to be implemented at Network Rail.

Chapter 8 – Discussion and Conclusion

8.1 Chapter summary

This chapter presents the general discussion of the work conducted for this thesis. The findings from all three studies are discussed in line with the aim, the objectives, and research questions of the thesis. On-call scheduling and management guidelines are provided based both on knowledge from existing literature and study findings. The desirability, ease of implementation, associated costs, and benefits and risks of implementing these guidelines were discussed with Network Rail's Head of Infrastructure Maintenance Safety and Compliance and the outcomes are discussed. The chapter concludes with the discussion of the limitations of the work presented in this thesis.

8.2 Background

The different chapters of this thesis described the difference stages of the research conducted. Chapter 1 presented the aim and specific objectives of the thesis. The overall aim of this thesis is to increase the understanding of on-call scheduling systems of work, and also to provide recommendations to the planning and management of on-call work in the rail industry. To achieve this, five objectives were outlined for the work to be performed. These were presented in the introduction chapter and are replicated below:

1. Identify and describe the on-call arrangements and management practices in place at Network Rail,
2. Describe the perceived work, social, and personal consequences of working on-call on workers,
3. Assess the relationships between the different factors at play in on-call work,
4. Develop an on-call specific framework where factors that are of importance are represented and so are the relationships between them,
5. Develop a set of research based guidelines on how to better manage the risks associated with on-call work,

Chapter 2 discussed the intricacies of the rail industry and the regulations that must be considered when investigating on-call work. These led to the emergence of on-call work as a topic worth pursuing in this thesis. Chapter 3 explored the available on-call literature, along with sleep disruption and shiftwork related literature leading to the prediction of the main expected unwanted outcomes of on-call work and the development of an initial on-call specific framework. Increased fatigue due to reduced sleep quantity and quality, increased anxiety, reduced well-being and impaired performance were the main unwanted outcomes predicted. The chapter concluded by also identifying the main theoretical and scientific questions that underpin the subsequent work conducted. These are:

- What are the on-call arrangements and management procedures at Network Rail?
- How do on-call workers feel about arrangements and management procedures?
- What are the main impacts of on-call work?
- How do workers experience and deal with these impacts?
- What is the relationship between callouts and the perceived consequences of on-call work?
- What is the relationship between on-call work arrangements and management procedures?
- What are the on-call specific characteristics that lead to consequences?
- How do these factors interact and what are the consequences?
- How can on-call work be monitored?
- What are the most damaging factors associated with on-call work and how can they be modified to reduce negative consequences?

Chapter 4 described the methods used for each of the three research studies conducted for this thesis: semi-structured interviews, questionnaire survey, and diary study. The chapter concluded by identifying how the main research questions of the thesis would be addressed by each of the methods. This is described in Table 4.5 (chapter 4) and replicated below.

	Research questions	Method
Objective 1	• What are the on-call arrangements and management procedures at Network Rail? • How do on-call workers feel about arrangements and management procedures?	• Semi- structured interviews • Questionnaire survey
Objective 2	• What are the main impacts of on-call work? • How do workers deal with these impacts?	• Semi- structured interviews • Questionnaire survey • Diary protocol
Objectives 3 and 4	• What are the on-call factors that lead to consequences and how do they interact? • What are the callout related factors that lead to unwanted consequences of on-call work?	• Semi- structured interviews • Questionnaire survey • Diary protocol
Objective 5	• How can the negative impact of the most damaging factors be reduced in Industry?	• Review of available literature • Semi- structured interviews • Questionnaire survey • Diary protocol

The results of each study were then presented and discussed in the following three chapters: Chapter 5 detailing the semi-structured interviews, chapter 6 the questionnaire survey, and chapter 7 the diary study.

The next section describes how the findings from each method relate to, and provide data regarding, each of the objectives and research questions of this thesis.

8.3 Objective 1: Identify and describe the on-call arrangements and management practices in place at Network Rail

Findings regarding this objective originate mainly from Study 1. This is due to the richness of the data collected from the interviews. The large sample of Study 2, however, also offers support for the generalisation of the findings. The research questions associated with this objective are discussed in detail below.

8.3.1 What are the on-call arrangements and management procedures at Network Rail?

From Study 1 it has been identified that there is a perception that the majority of on-call arrangements at Network Rail are managed locally. For example, the European Working Time Directive (93/104/EC), the Hidden limits, and Network Rail's own Management of Working Hours Standard (NR/L2/ERG/003) all state that a period of rest (12h minimum from NR/L2/ERG/003 and 11h from 93/104/EC) between periods of work must be provided[20]. Nonetheless, several interviewees (at least 18) reported working to eight, nine, and 11 hours rest instead of 12 hours. These were legacy terms and conditions from different contractor companies which were found to be enforced regarding frontline staff. Managers, on the other hand, who are responsible for managing their own hours, tend not to take all of the rest time available to them after being called-out (this was a consistent finding across the DUs assessed in Study 1). The receiver of the first callout was also found to vary across different locations. In some DUs the Section Manager receives the first callout whilst in others Fault Control calls frontline staff directly.

This apparent lack of standardised on-call arrangements and procedures regularly leads to staff being rostered to work on-call when on annual leave or when on a rostered day off. These findings were supported by Study 2 where 91% of respondents stated their on-call roster does not match their working hours arrangements. When this occurs, the responsibility to arrange cover usually falls on the on-call member of staff himself (84.1% of respondents). Study 1 also indicated that week-long rosters (i.e. one week in four weeks) are the preferred method of organising on-call work across Network Rail. This was further supported by Study 2 where 95% of all participants reported working under such on-call rosters. Another rostering option, explored by the remaining 5% of the respondents, is the use of day-long rosters (i.e. one day in seven days). Unfortunately, none of the interviewees worked under day-long rosters and the number of respondents to the questionnaire was too small to allow comparison between the two rostering methods. Within the available literature on-call arrangements do not tend to be discussed which limits the potential to compare results from separate studies (Imbernon et al., 1993; Nicol & Botterill, 2004).

Another unwanted consequence of the apparent lack of standardisation is confusion regarding who is on-call on a particular night, leading to the wrong person being called. Similarly, a large number of callouts were identified by interviewees as being unnecessary. For example, calls passing on irrelevant information, calls that were not deemed urgent and could have waited until the morning, and mainly, the need to constantly send and or receive updates on faults to or from several stakeholders. All

[20] For details see Chapter 2, section 2.5 Regulations.

these represent callouts or actions that could have been dealt with by other roles or at a different point in time. It is a recommendation of this thesis that on-call arrangements are standardised and monitored for their fitness for purpose and that clear guidelines are compiled on the types of incidents that require on-call staff to be involved. Where possible, the responsibility to deal with incidents should be shifted to roles with 24 hour coverage.

In theory, day-long rosters could be more beneficial to on-call workers by reducing the number of consecutive on-call shifts when disruption can occur. By working day long rosters the impact of on-call work on anxiety, fatigue, and health could potentially be greatly minimised. By only working on-call for one shift, even when receiving several callouts workers should be able to recover faster from the disruption as it will be limited to one night. Recovery time has been well established in the literature as a factor that further exacerbates the effects of fatigue (Åkerstedt et al., 2000; Belenky et al., 2003). This is a potential benefit that some interviewees are aware of, as a number of them stated that they would prefer to work day-long rosters over week-long ones. It is a recommendation for this thesis that future work into on-call scheduling systems should attempt to identify the differences between these two rostering systems and that on-call work standardised arrangements and procedures are implemented in industry.

In sum, from participants' perception, on-call arrangements and management procedures at Network Rail can be described as local instead of central with the following characteristics:

- Potential to be on-call when on annual leave or rostered day off,
- Rest time after callouts – up to 12 hours for frontline staff, self managed for managers,
- Week-long rosters,
- Lack of guidelines regarding the types of issues on-call staff should get involved in.

8.3.2 How do on-call workers feel about arrangements and management procedures?

Management issues were some of the topics more commonly commented on by interviewees in Study 1. Staff felt confused with the on-call arrangements in place and felt that there is a distinct lack of clarity regarding these arrangements. There is a perception that documentation regarding on-call arrangements is either non-existent, or so vague that staff are left confused and unsure of what qualifies as acceptable behaviours when on-call. Namely regarding:

- Amount of rest time after callouts,
- Accommodation arrangements versus long drives home,
- Response times to faults, so that workers know how much freedom they have to leave the house when on stand-by,
- Communication requirements – who needs to be involved and/or informed on each incident,
- Types of incidents or faults requiring called-outs,
- Details on specific roles, such as the role of the Asset Recovery Manager.

The non-existence of a relief system when on-call is another issue identified. Interviewees perceive that this creates situations were escalating work to the next on-call level is not always an option as some jobs require very specific skills. Moreover, current on-call arrangements, where only one member of staff is available per level do not afford much resilience to the system. This is perceived to leave on-call workers unable to request support without also disturbing other on-call staff who, in any case, might not be able to offer support due to the specific skills required.

There is also the perception that managers feel they need to now be much more proactive in their on-call staff management during the night, as staff who are called-out during the night require their rest break. This can mean that the manager might find himself short of staff to conduct the next morning’s planned jobs. The need to identify the best person or persons to attend a fault when on-call is one of the reasons for, in some areas, the manager receiving the first callout regardless of the severity of the fault. This offers further support to the recommendation to standardise, monitor, and when possible, reassign on-call work to other roles.

Culturally, some managers feel there is the expectation that they must be available around the clock to deal with calls (faults or incidents) regardless of being on-call or not. There is also the perception that they are required to be informed of any events that take place in their section of track, with managers being held responsible for any performance shortcomings. Similarly, some managers resent the level of involvement from senior managers in minor faults. This is perceived by participants as a confirmation that the company is too performance driven and that there is an excessive pressure to achieve objectives, resolve faults, and in fact to be more efficient and effective. The actual drive behind these changes was not assessed as part of thesis.

Not surprisingly, many of those interviewed dislike working on-call. A result that is further supported by the results from the questionnaire where 56% respondents stated they would prefer not to have to work on-call and with respondents on average not feeling satisfied with their on-call work. This is in line with other research investigating the impact of on-call work on physicians where it was found that physicians that work on-call for more than 40 hours per month reported having more turnover intentions than other physicians (Heponiemi et al., 2008). Stress, and anxiety in particular, have been found to be common when working on-call (Imbernon et al., 1993; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988), with on-call workers being found to have more depressive symptoms, and higher levels of tension and frustration (Rankin et al., 1987; Rout et al., 1996). Study 2 also supported these findings, specifically when staff are on stand-by but also identified that being required to work on-call when on leave, when on a rostered off day, and being required to maintain their normal working hours leads to higher levels of anxiety, and lower well-being.

In summary, on-call staff are generally unhappy with the current on-call arrangements. The perceived main areas of concern relating to:

- Lack of clarity on procedures,
- No relief staff and lack of frontline staff for day shifts,
- Micro-management,
- Expectation of availability,
- Performance driven culture,

8.4 Objective 2: Identify the perceived work, social, and personal consequences of working on-call on workers

Similarly to Objective 1, data relating to this objective also originated mainly from Study 1. Data from Study 2, however, also provided support for the generalisation of the findings and Study 3 provided real-time data on these findings. The research questions associated with this objective are discussed in detail below:

8.4.1 What are the main impacts of on-call work?

The impacts of on-call work were found to be dependent on the on-call scenario: stand-by, receiving callouts, and attending to callouts. Receiving callouts and attending callouts were, however, found to be more similar between them than to stand-by as both are caused by the reception of a callout.

When on stand-by, interviewees identified anxiety, fatigue, and sleep quality and quantity as the main factors affected. When receiving callouts, sleep disruption, difficulties in falling back to sleep, sleep quantity, sleep quality, well-being (measured through mood) and fatigue were identified. When actually having to attend a fault, fatigue from travelling (usually driving) to the fault was the one additional factor identified.

Feeling anxious when on stand-by was found to be common for many interviewees in Study 1. Results from Study 2 and Study 3 further support these findings, where respondents stated their anxiety when on-call is, on average, moderately high, and significantly higher when on-call when compared to not being on-call. Study 3 further showed that anxiety is significantly higher when on stand-by when compared to not being on-call but that anxiety when receiving callouts is significantly higher than when on stand-by or when not on-call. Anxiety when on-call has also been identified initially by Torsvall & Akerstedt (1988) where it was identified that on-call workers suffered from anxiety which the authors suggest was due to apprehension or uneasiness from the prospect of being awakened by an alarm. A further two studies have also identified higher anxiety levels for workers when on-call (Imbernon et al., 1993; Pilcher & Coplens, 2000).

Affected sleep was also identified by interviewees as a consequence of being on stand-by. A consequence supported by Study 2 where both sleep quality and quantity were found to be reduced when on-call when compared to not being on-call. Further, being on-call and receiving callouts was perceived as the most damaging scenario to sleep in general. Similar results were also found in Study 3 regarding sleep quantity but with sleep quality only being identified as significantly worse when comparing the on-call week with the not on-call week. These are not surprising results, as sleep quantity is bound to be reduced after a callout. Sleep quality might, however, be more resilient to disruption. Sleep fragmentation research goes some way to support this where sleepiness has been correlated to the number of arousals in periods of consolidated sleep that are long enough to cause disruption. This means that the length of the disruption, not the disruption itself, plays a bigger part in sleepiness (Stepanski, 2002). In accordance to this, and other research (e.g. Bonnet & Arand, 2003; Martin, Engleman, Deary, & Douglas, 1996), the relationships between the level of sleep disruption and sleep quality may be more subtle than the design or sample size of the study were able to identify. To investigate this, it is a recommendation of this thesis that future studies are comprised of larger data samples and that further variables (e.g. sleep stage) are considered.

When receiving callouts, interviewees stated that a period of time to wake up and prepare themselves to take the call is required. This effect is known as sleep inertia, a well-known phenomenon in sleep research (e.g. Hofer-Tinguely et al., 2005; Jewett et al., 1999). Surprisingly, however, the majority of interviewees did not perceive their performance to be impacted after conquering sleep inertia (having given themselves a few minutes to wake up). This is contrary to the literature where sleep disruption was found to significantly affect performance (e.g. Martin, Engleman, Deary, & Douglas, 1996; Murray & Dodds, 2003) but these results are supported by Study 2 and Study 3. In Study 2, 70% of respondents feel their performance is not impaired or moderately impaired when on-call and participants of Study 3 felt able or very able to deal with 66.3% of all callouts.

Interviewees also identified the actual interruption of sleep and the subsequent difficulties in falling back asleep after receiving a callout as the main consequences of callouts, with these effects also spreading to partners and children who might also be woken by the callout; expanding the impact of callouts beyond the workers themselves. This is an effect that has also been identified by previous research where callouts were found to disturb the remainder of the household (Imbernon et al., 1993). It was common for interviewees to find it difficult to fall back to sleep after callouts. Interviewees stated that this is due to reviewing the decision or advice given regarding the callout. During the day, callouts also impact on family time and cause disruption to family and social events. Results from Study 2 further supported these findings by showing that respondents feel that, on average, their partners are unhappy about their requirement to work on-call. In effect, only 13.3% of respondents believed their partners to be happy or extremely happy with their on-call work.

Increased fatigue on the days following callouts and through the on-call week were also reported by interviewees as an outcome of on-call work in general but more so when receiving callouts. Cumulative fatigue due to extended wakefulness has been clearly identified in literature (e.g. Van Dongen, Maislin, Mullington, & Dinges, 2003), so this was an expected outcome. Increased next day fatigue was supported by Study 3. However, Study 3 did not support the existence of cumulative fatigue during the on-call weeks assessed. This was an interesting result. It could be that a cumulative effect is not present as on-call work does not in itself necessarily require extended wakefulness and that sleep disruption in itself is not sufficient to cause a cumulative effect. It is also important to remember that participants in Study 3 did not receive callouts every day, indicating that sleep disruption did not occur for everyday of the week, therefore allowing for restoration to occur.

8.4.2 How do workers deal with these impacts?

From Study 1 it is known that when on stand-by, preparing for the reception of callouts (e.g. keeping track diagrams close at hand, knowing which work is taking place and where) is important to prevent being caught off-guard. Similarly, planning family and social lives around on-call work is also a key strategy to deal with on-call work. Holidays and family and social events are booked in advance to match not on-call weeks. However, the most commonly used strategy is to swap shifts with a co-worker or to get a co-worker to cover part of a shift so that events can be attended (e.g. a son's football match). Shift swapping is also used by on-call workers when feeling fatigued, especially after a few consecutive nights with long callouts. Pursuing a hobby is also a coping mechanism. Some interviewees stated that having and maintaining hobbies helps to manage the anxiety generated by being on-call.

After nights where callouts are received, managerial level staff, who tend not to have a full 12h rest, find other ways of coping. By starting the day a few hours later or by leaving earlier, managers attempt to manage their fatigue and prepare for another potential disrupted night. Regardless of this, taking naps was not reported as a coping mechanism. This could be due simply to culture where railways traditions and culture do not include napping as a fatigue coping mechanism. Other on-call research (on *proximal* on-call) has identified a significant increase in napping times on post on-call days vs. non on-call days (Van Gelder & Kao, 2006). Napping is also extensively used as a coping mechanism for fatigue in other industries, such as the aviation industry, generally with positive effects being found (e.g. Della Rocco, Comperatore, Caldwell, & Cruz, 2000; J. J. Pilcher, Popkin, Adkins, & Roether, 2005).

The list of coping mechanisms was, in effect, shorter than what could be anticipated. Nonetheless it must be recognised that the ability to swap and cover shifts that is allowed at the moment represents a high level of flexibility of the system. The lack of extensive coping mechanisms might be a reflection of how resilient this method is. At Network Rail, such a system represents a solution on-call workers devised to better manage the disruption to their family and social lives and also to manage fatigue. Although there are clear advantages to the system there are also problems. One of them is that it works as in so far as all parties involved are willing to abide by it and there are mutual benefits to the swap. If a few members refuse to participate in the swap the resilience is lost. As discussed before, it is a recommendation of this thesis that on-call arrangements are standardised. This does not mean that the existing ability to swap shifts should be eliminated. The company, however, should be cognisant of this practice and should aim to manage it based on the best possible stress and fatigue guidance.

It is a recommendation of this thesis that future work should assess similar informal arrangements for their resilience and potential benefits for the management of on-call related fatigue, stress, and well-being.

8.5 Objective 3: Assess the relationships between the different factors at play in on-call work

Having established basic patterns, practices and attitudes for on-call work (objectives 1 and 2), it was possible to build a theoretical model. This model draws on both the body of literature of on-call work, and related areas such as shift and sleep disruption work (Chapter 3), and on the results of each of the studies conducted (Chapters 5, 6, and 7). Objectives 1 and 2 of this thesis identified the main factors involved in on-call work (on-call arrangements and consequences). For this, Study 1 with its exploratory nature, was essential. Although it provided the first indication of a relationship between the different factors, Studies 2 and 3, specifically, aimed to understand these relationships. As a result, although data from all three studies were used to achieve this objective, data from Study 2 and Study 3 were the main contributors to this.

8.5.1 What are the on-call factors that lead to consequences and how do they interact?

Study 1 identified that anxiety when on stand-by arises from the anticipation of receiving callouts. Ongoing work and poor weather were identified as the two reasons that lead to this. The main reason for high anxiety, however, was described as the unpredictability of knowing when a callout will take place. Similar results have also been found by other research (Imbernon et al., 1993; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988). The same unpredictability leads to impacts on well-being with on-call staff many times choosing to remain indoors and shy away from social events in anticipation of a callout.

8.5.1.1 Stand-by

When on stand-by interviewees believed this anxiety is a cause of reduced sleep quality; findings which were also partly supported by Studies 2 and Study 3. Results from Study 2 identified that the higher the anxiety when on stand-by, the lower the sleep quality. Results from Study 3 supported these findings regarding on-call work in general but no support was directly found between on-call scenarios. The reception of callouts is unpredictable so these are not surprising results as, at the beginning of an on-call shift, the shift can either become a stand-by or a callout shift.

Interviewees also believed anxiety had a negative impact on their amount of sleep. Results from Study 2 supported this but results from Study 3 did not. Study 2 found that sleep quantity was significantly reduced when on on-call versus when not on-call and also between on-call scenarios with receiving callouts being the most affected scenario. The same study also found statistically significant support for the hypothesis that the higher the anxiety felt by respondents, the higher the impact on their sleep quality when on stand-by. Study 3, however, found no significant differences between sleep quantity when on stand-by versus when not on-call and no statistically significant relationship was identified between anxiety at the beginning of an on-call shift and sleep quantity. Sleep quantity is expected to be reduced when receiving callouts as these cause sleep disruption and require work to be conducted. This on-call scenario is discussed in detail further below.

It was thought that reduced sleep quantity when on stand-by could be due to increased sleep latency. This was assessed in Study 3 but no differences between the on-call and not on-call weeks or between on-call scenarios was found. No support was found, either, regarding high anxiety at the beginning of an on-call shift and sleep latency.

The disparity in these results is interesting but not completely unexpected as anxiety was expected to reduce sleep quality but not necessarily sleep quantity. It could also be that the vulnerability of Studies 1 and 2 to recollection bias or that the sample size of Study 3 was insufficient to represent these findings. The limitations of each of the studies are discussed in greater detail below in section 8.8 Limitations and in greater detail together with recommendations on how future research can overcome these.

Interviewees also believed that on-call work, through heightened arousal and reduced sleep quality, leads to increased fatigue. This is partly supported by both Study 2 and Study 3. In both studies fatigue was found to be significantly worse when on-call than when not on-call and Study 3 found support for the hypothesis that the higher the sleep quality when on-call, the lower the fatigue the next morning. No support was found, however, for the hypothesis that sleep quality mediates the relationship between anxiety at the beginning of an on-call shift and fatigue the morning after. These findings indicate that the relationship between anxiety, sleep quality, and fatigue is a complex one and may be dependent on other factors (e.g. individual factors, on-going work).

8.5.1.2 Receiving callouts

When receiving callouts, whilst still awake, disruption to their family and social lives were the main consequences identified by interviewees. These findings were supported by Study 2, which further identified that the longer the maximum period working on-call, the lower the satisfaction with the amount of time on-call work leaves for personal life. The same study also found that being required to work on-call when on leave, when on a rostered off day, and being required to maintain normal working hours leads to perceived higher levels of anxiety, and lower general well-being.

When already asleep, interviewees identified that sleep disruption caused by callouts leads to reduced sleep quantity. This was an expected outcome as both other on-call research (Van Gelder & Kao, 2006) and sleep disruption research (e.g. Bonnet & Arand, 2003) have found support to this hypothesis. The reasons for this have not been discussed in research but from Study 1 of this thesis is seems that this is both due to the amount of sleep lost whilst dealing with the call and to the inability to simply go back to sleep after being woken, replaying their conversations and decisions in their minds. This replaying of thoughts when back in bed was also identified as disrupting sleep quality. Findings from Study 2 further supported this, with results identifying that both sleep quantity and quality are lower when receiving callouts than when on stand-by. Study 3 also partly supported these findings where sleep quality was found to be reduced when on-call versus when not on-call. However, only sleep quantity was found to be significantly reduced when receiving callouts when compared to a non on-call week. Interestingly, no differences were found between the on-call scenarios (stand-by and receiving callouts) both regarding sleep quantity and quality. This, despite the median time required to fall back asleep after a callout being 40 minutes and with 28% of calls requiring an hour or more. The results indicate that even though the reception of callouts most definitely has an impact on sleep quality and quantity, call specific details must also have an influence. Call length, call timing, and number of calls are some of these and their influence is discussed in detail in the next research question of this objective.

Interviewees stated also that the reception of callouts leads to increased fatigue, through reduced sleep quantity and quality, both during the next working day and across the on-call week. This assertion is supported both by literature (e.g. Åkerstedt, 2000) and by Study 2 where, not only fatigue, but also stress and performance were found to be affected by the number of callouts received during the night. Study 3 further corroborate this where support was found for the hypotheses that the higher the sleep quality and quantity when on-call, the lower fatigue of participants the morning after.

Impaired mood, as one of the consequences of fragmented sleep, has been one of the factors identified both by sleep disruption research (Bonnet & Arand, 2003) and on-call research (Saxena & George, 2005; Wesnes et al., 1997). It was also mentioned by a small number of interviewees in Study 1, and Study 2 also found some support for this through reduced well-being. Study 3 aimed to clarify this effect and the results have found further support for this effect. Mood was found to be significantly worse at the end of an on-call day than a not on-call day and worse in a night when callouts were received versus a stand-by night. However, in the morning, after the actual disruption, mood was only found to be significantly worse when on-call versus when not on-call. No differences were found between on-call scenarios. These results indicate that on-call work in general causes reduced mood at the end of a normal shift / start of on-call shift. The events of the night, however, seem to have no impact on mood in the morning.

Impaired performance, an expected negative outcome of sleep disruption due to callouts, was remarkably mentioned only by a small number of interviewees. Similarly, in Study 2 respondents indicated that on average they perceive performance to be only slightly impaired when dealing with a callout with 70% stating their performance is not impaired. Study 3, looking at specific callouts, also identified that participants felt able to deal with around three fifths of all callouts (66%). However, regardless of the general perception that performance is not greatly affected, Study 3 also found that the ability to perform tasks is more affected when woken by a callout than when still awake. These results indicate that although participants perceived performance not to be greatly affected by callouts, callouts that disrupt sleep do cause performance deterioration. Similar findings have been found in research where two on-call studies with medical interns have investigated the impacts of on-call work on performance and found a relationship between on-call work and impaired cognitive performance (Saxena & George, 2005; Wesnes et al., 1997). However, another study, also with medical interns, found no differences between interns' performance post on-call period and controls (Kiernan et al., 2006). This indicates that the relationship between on-call work and performance is a complex one that must be investigated in greater detail than this thesis and other studies have done so far.

The next section, by discussing the idiosyncrasies of callouts and how these can lead to the identified unwanted consequences of on-call work, will shed some light on this. It could also be that these findings reflect a weakness of the research protocol as it relies on the recollected perceptions of participants or that participants are just very poor at identifying how affected they are. This inability to recognise how much performance is affected has been documented in literature regarding extended wakefulness both in real world research (David Dinges et al., 1997) and later verified in a laboratory study (Van Dongen, Maislin, et al., 2003). These results could indicate that a similar effect also occurs when sleep disruption is involved. Although sleep disruption research has found some support for performance as one of the negative outcomes of fragmented sleep, no assessment, as far as the author can identify, has compared perceived performance scores with actual performance scores. To explore the existence of this effect it is a recommendation of this thesis that future work explores the impacts of sleep disruption, from on-call work, on perceived performance scores versus actual performance scores. Another possibility lies in the type of tasks to be performed. Recent research into extended wakefulness has found that tasks involving challenging situations with high levels of uncertainty, change, distraction, and capacity to evaluate risks are more at risk seemingly due to the deterioration of supervisory executive functions of the prefrontal cortex (Horne, 2012; Tucker, Whitney, Belenky, Hinson, & Van Dongen, 2010). It can be that the tasks performed by on-call staff are mainly associated with well known events that carry little change, thus not impairing performance.

8.5.1.3 Other factors

Shiftwork research has identified a large number of individual factors which are known to mediate the relationship between shiftwork characteristics and unwanted consequences. Age, circadian typologies, gender, personality, and experience have all been found to mediate these consequences (e.g. Duclos et al., 2012; Folkard & Hill, 2002; Natale & Alzani, 2001; Saksvik, Bjorvatn, Hetland, Sandal, & Pallesen, 2011).

Although the investigation of individual factors was not an objective of this thesis, the role of experience and age were mentioned by some interviewees in Study 1. Similarly to the findings from shiftwork research they believed that their experience allowed them to better deal with the anxiety caused by being on-call. This was not supported by Study 2 or Study 3, where no relationship between experience and anxiety was found. However, Study 2 identified that higher levels of experience were found to lead to better sleep quality, but only after the reception of callouts. Study 3 did not support this, where no relationship between experience and sleep quality was identified in either on-call scenario. The relationships between age, anxiety and sleep were also assessed with Study 2 finding no effect of age on quality of sleep across all on-call scenarios. Study 3 presented similar findings where no relationship was identified either with sleep quality or with anxiety scores. These results indicate that, contrary to what shiftwork research has identified, younger on-call workers do not seem to be better able to deal with the consequences of this type of scheduling system. It must be recognised, however, that more research into the effects of individual factors was not an objective of this thesis and much more research into these relationships is required.

8.5.2 What are the callout related factors that lead to unwanted consequences of on-call work?

As discussed in the previous section, the simple reception of a callout leads to unwanted consequences (e.g. reduced sleep quantity) and so does simply being on stand-by (e.g. anxiety). Call specific factors that lead to increased disruption were also indicated by around one quarter of interviewees in Study 1. These relate to callouts that take place when asleep and involved the length and timing of callouts. The specific influences of these factors on the consequences of on-call work have not been investigated by the available on-call research. Sleep disruption research, however, has identified that the disturbance of sleep continuity is the responsible factor of influence on sleepiness (e.g. Bonnet & Arand, 2003; Stepanski, 2002).

8.5.2.1 Length

Interviewees in general stated that longer calls are more disruptive as they require longer periods to fall back to sleep. This impact was supported by Study 2 where the results identified that the higher the percentage of calls that keep respondents awake for more than 30 minutes after a callout, the lower well-being and quality of sleep when on-call and receiving callouts. Study 3 also found support for the relationship between length of callout and sleep quality with very short calls (< = 10min) being less disruptive and between length of call and the amount of time required to fall back to sleep. Study 3 also found support for the hypothesis that the longer the callout the longer the amount of time required to go back to sleep.

8.5.2.2 Timings

Contrary to call length, no clear agreement was found in Study 1 regarding call timings. Around 50% of the interviewees that identified callout timing as a disrupting factor believed calls have a greater impact when taking place a number of hours after going to sleep. The remaining 50% believed that a greater impact comes from calls in the early hours of the night. Study 2 found further support regarding this impact with 66% of respondents believing there is a worst time to be called-out and the majority of these (83.9%) stated that being woken two to four hours after falling asleep has the most damaging effects. The remaining respondents believed that callouts received from around 2300 to 0300 hours are the most damaging.

Study 3, aiming to explore this relationship, assessed the fatigue impact of received callouts after being asleep for a number of hours. The results did not support the hypothesis that the longer the period of time participants have been asleep for before receiving a callout, the lower the fatigue levels experienced in the morning. Study 3 also assessed the perceived impact of receiving callouts per time of day with results indicating that participants' ability to deal with callouts was more compromised when asleep. Based on these results one of the recommendations of this thesis is that callouts during the hours of 2400 and 0600 are minimised. These results indicate that the timing of callouts is an important factor to consider when preparing on-call rosters but that more understanding and research is still needed to understand callout timing characteristics.

8.5.2.3 Numbers

Number of callouts was expected to be one of the most relevant factors leading to unwanted consequences. However, number of callouts was only mentioned by three interviewees in Study 1 and solely as an impediment to falling back to sleep after receiving a callout. Interestingly, Study 2 found that participants also perceived that the higher the amount of callouts the higher the impact on fatigue, stress, and performance. Study 3 aimed to further explore these incongruent findings and the relationship between number of callouts and the amount of time required to fall back to sleep, fatigue, and performance. No support was found between number of callouts and the time needed to fall back asleep, or anxiety the morning after. Mood the morning after was also found not to be affected by the number of callouts. A positive relationship, however, was found between number of callouts and fatigue the morning after.

A potential reason for these results lies in the actual number of callouts participants received. Results from Study 2 show that 70% of participants receive four callouts or less on average per on-call week or an average score of 0.57 callouts per participant per week. Results from Study 3 were very similar with a small number of callouts received during the on-call week (a total of 204) equating to 0.76 callouts per participant per week. It was also clear, however, that a large variance in the numbers of callouts also exists. Some participants (three) received up to 20 callouts during their on-call week whilst some received none. It could be that the majority of participants of Study 3 had an unusually quiet on-call week or that the participants that volunteered do not represent those that are most affected.

In summary, it can be said that the results of this thesis have identified and found support through the different studies to many relationships between on-call work factors. The next objective presents and describes in a diagrammatic format the interactions between the factors discussed in this objective together with those discussed in the previous objectives.

8.6 Objective 4: Develop an on-call specific framework where factors that are of importance are represented and so are the relationships between them

To achieve this objective in the early stages of the work an initial framework was developed based on the available literature. Due to the small amount of available on-call literature the framework was based as much on this literature as it was on shiftwork literature. Each of the research studies conducted afterwards built on it through the incorporations of their findings.

The initial relationships identified in the literature, the majority from *proximal* on-call research, were increased anxiety (Imbernon et al., 1993; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988), reduced sleep quantity when on-call (Van Gelder & Kao, 2006), increased sleepiness on day after working on-call (Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988), decreased sleep quality when on-call (Pilcher &

Coplens, 2000; Torsvall & Akerstedt, 1988), impact on the well-being of workers and their family life (Imbernon et al., 1993), decreased mood (Saxena & George, 2005; Wesnes et al., 1997).

The final iteration of the framework presented in Figure 7.7 in chapter 7 combines the data collected throughout this thesis and represents, as far as the author can identify, the first data driven on-call specific framework. The framework is shown below in Figure 8.1 with emphasis placed on the factors that have been supported by the three studies conducted for this thesis. The findings of each of the three studies of this thesis were used to iterate the framework. As greater clarity regarding each of the relationships was identified in each study, so was the framework updated. The final iteration with the findings from Study 3 represents the culmination of all available research on on-call work and presents this information and relationships between factors in an easy to read diagrammatic format that can be used both by industry and academia to direct research and on-call management practices. As the first such framework it is a major scientific contribution of this thesis and it is hoped that the framework will be used, and built upon, across industries and academia to continue to identify and support management decisions regarding this type of working hours scheduling system.

The framework identifies the key factors at play, from planning an on-call roster to the outcomes arising from each of the on-call scenarios identified by Study 1. When the roster is rolled out it is shaped by on-call arrangements and moderated by the roster's duration, frequency, and notice period. The combinations of these arrangements shape the final format of the roster and its potential for leading to unwanted outcomes.

When the roster is in place it is then ready to be implemented. On-call work starts with staff being on stand-by. This scenario can be affected by the cover arrangements in place, the need to maintain normal working hours, annual and rostered days-off arrangements. All these factors, if not managed properly, can lead to increased anxiety affecting sleep quality and quantity and increasing fatigue. These also cause ad-hoc changes to the roster, causing further disruption across the work to be conducted during the day and on on-call rosters. Team work and the flexibility, available at Network Rail at the moment, for on-call staff to swap shifts and cover parts or shifts amongst themselves are the main mitigating factors identified to prevent unwanted consequences. These are present and are used across all on-call processes, both before the implementation of on-call work (being on stand-by), between the implementation and occurrence of on-call events (receiving callouts) and after an event occurs.

When on-call events do occur many factors have an influence on the relationship between the callouts and unwanted outcomes. These are callout associated factors (duration, timing, and number of callouts), sleep related factors (was the on-call worker asleep? If so, what was the amount of sleep taken before receiving the callout?), and individual factors (e.g. personality, hobbies, rest requirements). On-going work and weather are the two other factors that are also present. The main affected factors from callouts are also represented in the framework. These are workers' family and social lives, job satisfaction, sleep quality and quantity, leading to an impact on fatigue and impaired ability to perform on-call duties.

It must be recognised that all the factors and their relationships in the framework have complex relationships. As such, although relationships between factors have been identified it must also be recognised that, similarly to other working hours scheduling systems, on-call work will also be affected by a number of unpredictable and uncontrollable events (e.g. fatigue may also be caused by a young toddler's sleep difficulties). Moreover, it must also be recognised that although the framework identifies linear and even causal relationships between the factors, a cyclical relationship is present in these systems. Unwanted outcomes (e.g. fatigue, stress) necessarily have an effect both on the consequent implementation of on-call work and the way workers deal with on-call events (e.g. swapping a shift due to fatigue). At Network Rail, this happens through informal processes and is addressed through team work and the swapping and covering of shifts but in other industries it may be addressed in a different way. Nonetheless, regardless of the different formats these processes can take in each industry it must be expected that they will be present in each on-call scheduling system.

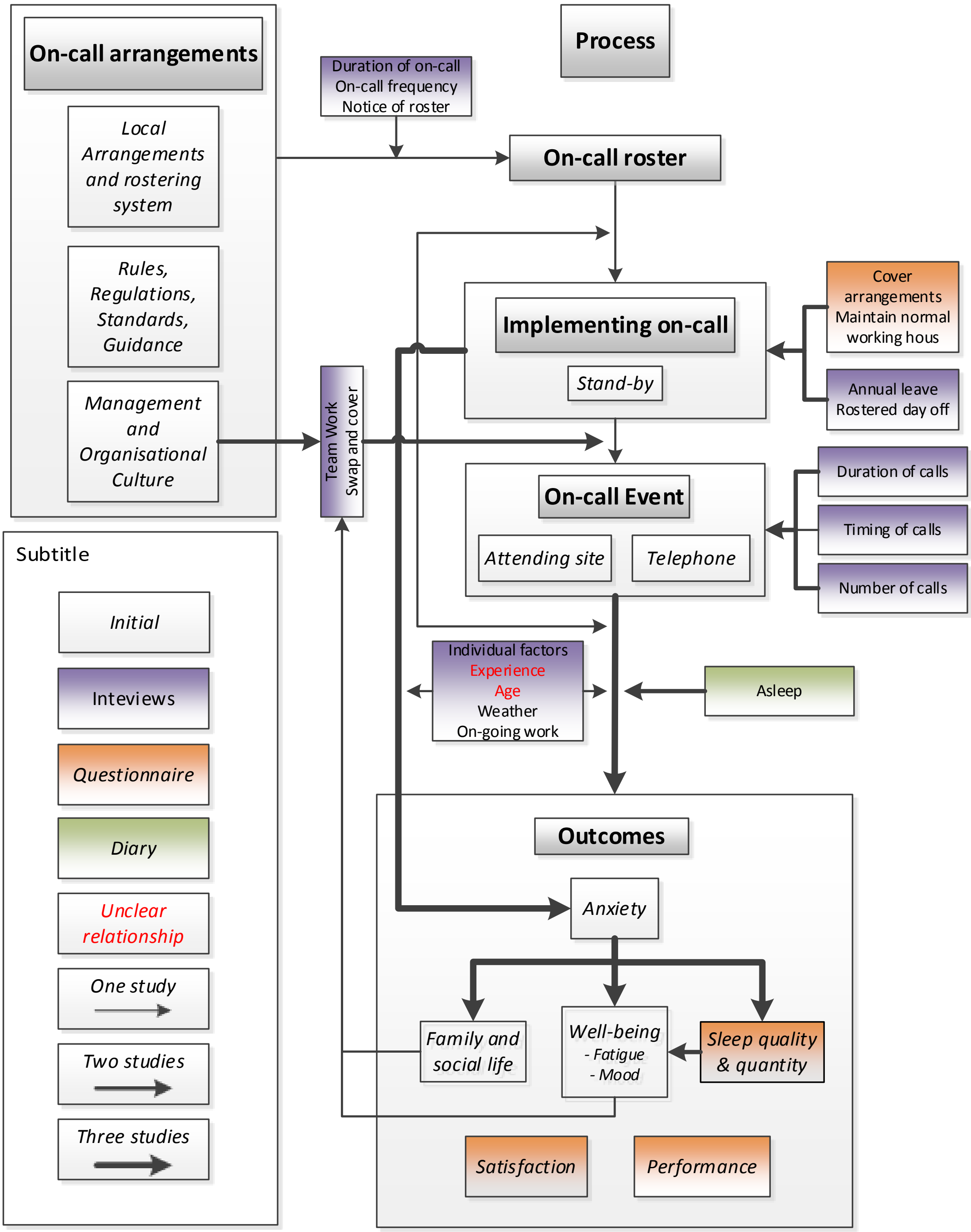


Figure 8.1- Final Framework with factors and relationships supported by number of studies represented by line thickness

8.7 Objective 5: Develop a set of research based guidelines on how to better manage the risks associated with on-call work

In Chapter 2 the prevalence of on-call work in modern industry was discussed. On-call work although being a relatively new form of providing 24 hour monitoring is now a common form of scheduled work. In the European Union (EU) 20.2% of the workforce now already operates under one on-call schedule or another (Eurofound, 2012).

That a large number of people in Network Rail and other industries across Europe already work under this system makes this research crucial in order that sensible risk management policies and actions can be put in place. As far as the author is aware, on-call research to date has yet to produce a set of specific on-call guidance or management recommendations. The production of said guidelines based in science and research would be of great advantage to industry in general and can only benefit on-call workers.

The following guidance (full document in Appendix I – On-call guidelines) and recommendations were composed based on all the pieces of work conducted for this thesis:

- Define a clear list of appropriate events that require on-call staff to be disturbed. These should be role dependent and should be compiled accordingly,
- Define a clear list of stakeholders that must be involved and/or informed regarding specific incidents,
    - A Responsible, Accountable, Contributing, Informed (RACI) document could be produced to make this simple and clear to all involved in the process,
- Move on-call responsibility for as many of these events as possible to 24/7 roles, i.e. Fault Control
- Limit calls after 22h and no calls between 00:00 and 04:00. This can be achieved by:
    - Identifying levels of urgency for each event. Only high emergency calls should be routed to on-call staff,
    - Creating call windows – where instead of being on-call for the whole night on-call staff are given a specific time window to receive callouts (e.g. until all possessions are taken),
    - Transfer night shift staff management responsibilities to a 24/7 role where possible,

- After being called-out, provide staff with 12h rest breaks to meet the legal requirements of the European Working time Directive 2003/88/EC, and Network Rail's Management of Working Hours standard NR/ERG/003.

- Regularise and manage on-call rosters centrally:
  - On-call staff should not be booked to work on-call during days off or when on annual leave. This prevents actual breaks from work.
  - Mistakes are known to occur when on-call staff have been called-out when not actually working on-call.
- Implement an on-call monitoring system to:
  - Monitor numbers and timings of callouts,
  - Assess callout trends,
  - Allow for live modifications to on-call rosters to better manage trend peaks and staff fatigue.

The key findings of this thesis which support the key guidance points are presented below in Table 8.1. The recommendations simply present potential ways to achieve the guidance and are based on existing Network Rail systems or sections (e.g. Fault Control), based on existing management tools (e.g. RACIs), and based on legal requirements (European Working time Directive 2003/88/EC). Therefore, these are not discussed in the table with regards to findings of this thesis.

Table 8.1 - On-call guidance basis

Guidance	Basis
Define a clear list of appropriate events that require on-call staff to be disturbed,	Study 1: Callouts identified as often being unnecessary. For details refer to section 5.4.3 Theme 3: Receiving callouts (5) Reasons to be called-out
Define a clear list of stakeholders that must be involved and/or informed regarding specific incidents,	Study 1: Lack of clarity as key issue with management of on-call work. Also, currently there is a need to send out constant updates to several parties. For more details refer to sections 5.4.3 Theme 3: Receiving callouts (5) Reasons to be called-out and 5.4.6 Themes 6, 7 & 8: On-call arrangements, Management of on-call work, & Organisational culture(1 1) Management Problems

Move on-call responsibility for as many of these events as possible to 24/7 roles, i.e. Fault Control	Studies 1, 2, and 3: Anxiety and fatigue are key consequences of on-call work and sleep disruption. Preventing disruption will improve on-call workers general well-being. Network Rail already has a number of 24/7 roles that could potentially deal with a large number of these callouts.
Limit calls after 22h and no calls between 00:00 and 04:00.	Study 1: Calls that disrupt sleep seen as key cause of fatigue. For details refer to section5.4.3 Theme 3: Receiving callouts(3) Fatigue Study 2: Although no support of found for negative outcomes arising from timing of callouts, calls that occur after having gone to sleep found to be more damaging to fatigue, stress, and sleep quality. From Study 1it can be assumed that at 00h to 04h are the core sleeping hour. For details refer to section 6.5.4 Sleep. Study 3: No support found for time of callouts and negative outcomes also however similar findings regarding fatigue and sleep quantity and quality to those of Study 2. Refer to section 7.5.3.1 Sleep for details.
Regularise and manage on-call rosters centrally	Study 1: Being rostered on-call whilst also when annual leave or on a rostered day off is common. For more details refer to section 5.4.6 Themes 6, 7 & 8: On-call arrangements, Management of on-call work, & Organisational culture(1 4) Rest days. Study 2: 91% of respondents stated being rostered on-call whilst also on annual leave is possible. 79.3% stated that being rostered on-call whilst on a rostered day off is possible. For details refer to section 6.5.2.1 Roster arrangements Central management will facilitate management of on-call rosters and management of short notice changes (e.g. shift swapping)

Implement an on-call monitoring system	Study 1: Length and timing of callouts identified as key causes of unwanted outcomes of on-call work. For details refer to section 5.4.3 Theme 3: Receiving callouts(1) Sleep Disruption Study 2: Results indicate that number of call-outs, length of callouts, and timing of callouts found to be correlated with unwanted outcomes (e.g. fatigue). For details please refer to Table 6.22. Study 3: Number of callouts and length of callouts found to be correlated with unwanted outcomes (e.g. fatigue). For details refer to Table 7.26. An on-call monitoring system would allow a better management of the number of callouts than one member of staff receives thus allow for improved well-being.

To assess the appropriateness of these guidelines for the industry and how achievable these are given business needs and constraints, an interview on the feasibility of the guidelines was conducted with Network Rail's Infrastructure Maintenance Head of Safety and Compliance. The following four areas were focused on:

- Desirability,
- Ease of implementation,
- Associated costs,
- Benefits and risks of implementing.

The guidance was mainly well received but concerns were raised on the business practicalities of limiting the number of calls between 00:00 and 04:00, and also on providing staff with 12h rest breaks after a call-out. A way forward was agreed for the business where on-call management principles based on these guidelines were produced by the author with consultation with Network Rail's Principal Organisational Psychologist (Emma Lowe) and the Head of Safety and Compliance (Alan Brookes). These were presented to Network Rail's Fatigue Risk Management Steering Group on July 8th 2013. The principles were well received, with the group endorsing the principles and committing to implement them across the company. The management principles agreed are presented below (for the full document see

Appendix J – NR's On-call management principles).

- Minimise numbers of calls,
- After a call, minimise disruption and length of on-call work,
- Implement an on-call monitoring system,
- Limit number of calls per on-call shift,
- Regularise and manage on-call rosters centrally.

In sum, the delivered results of this thesis have been well received by the business and the rail industry, are progressing towards the implementation within Network Rail's Fatigue Risk Management System, and have been shared with the Rail industry at large.

8.8 Limitations

In conducting any research, and in particular when considering research in a real world complex system, there are limitations. This research was no exception to this.

The difficulty of investigating the on-call scheduling system of work for rail maintenance workers laid on the large variance of arrangements, procedures, reasons to be called-out, and the number of tasks to be performed when called. On-call work being performed by highly qualified technical workers meant that on-call tasks were tremendously varied, which made it impossible to measure performance accurately. The unpredictability of identifying when callouts will occur and the fact that on-call workers are at home when this occurs were other major difficulties of this research.

8.8.1 Study 1

Interviews are a particularly useful way to start an investigation into a subject the researcher has limited knowledge of, as the responses may identify issues that the interviewer had not considered. This was indeed the case for this research. Participatory bias and recollection bias are two of the main limitations of this type of study. Due to the selection method in this research participatory bias is a possibility as participation was voluntary. Recollection bias (see Stone & Shiffman, 2002)and potential deception, however, are clear limitations of qualitative research and of this study. It must also be assumed that there is a degree of memory degradation and that interviewees might have exaggerated in their answers in an attempt to inflate the impacts of on-call work.

Another limitation that must be considered is the individual judgment to interpret the data. It is advised that when using qualitative methods, researchers work on the data and cross reference the data grouping and theme allocation with each other (Miles & Huberman, 1994). This was not possible in this research as only the author worked on the project. Qualitative research tends to also have limited external validity making the generalisation of results difficult. However, generalisation for on-call work scheduling systems sharing the same characteristics (e.g. *distal* on-call work, week-long rosters) can be assumed.

8.8.2 Study 2

Similarly to Study 1, recollection bias and potential deception are also clear limitations of qualitative research and of this study. Participatory bias is also a limitation of this study, although, the large level of participation (60% response rate) goes some way to reduce this. Question priming and potential for respondents to have different interpretations of the questions, which in turn will result in disparate answers, are further limitations of questionnaire studies. The sequencing of questions was carefully planned with priming, funnelling and reverse funnelling (Hayes, 2000) carefully used, drawing also on existing relevant surveys (REQUEST and the Standard Shiftwork Index). Nonetheless, there is still the possibility that respondents' states of mind varied leading to disparate answers. The choice of the questions to be included in the study are also a limitation of questionnaire studies where the researcher makes assumptions of what qualifies as a relevant topic or area of research. More than this, although the questions were drawn from other tools, the majority of these did not originate from validated scales, and those that did were modified to reflect on-call work instead of shiftwork, limiting their validity. Study 1 helped to reduce the impact of this limitation on this study as it identified the main areas that further research should focus on.

8.8.3 Study 3

To address the recollection bias of the previous studies, Study 3 aimed to collect real time scores. The main limitation in doing so was the inability for the researcher to be present when callouts occur as these take place when on-call workers are at home. Although diary studies eliminate recollection bias they are still vulnerable to deception and to participatory bias. Diary studies tend to have smaller samples due to the time commitment from participants. This can lead to participatory bias where only participants that have strong ideas or feelings regarding the research area are willing to commit the time. It can also be that those that are more affected feel so affected that they are unable to spare the time. In the event of the latter, an inflation of scores could be expected and in the event of the former a depression. For the reasons discussed in section 8.5.2.3 Numbers, it seems the former might be the case. Both of them, however, lead also to small sample sizes making the generalisation of results limited. Study 3 was further limited by the nature of on-call work. Participants were on-call on different weeks (as their on-call roster began), in different locations across GB, potentially operating under different arrangements (e.g. Section Manager being the first point of contact versus frontline staff, for more details refer back to section 5.4.6 of Chapter 5). This makes the generalisation of results even more complicated as the impact of these confounding factors is unknown. A further limitation of this study relates to the scales used as these were aligned with those used for Study 2 to maintain consistency. As a result some of the scales used were not validated scales, further limiting the validity of the results.

8.8.4 General issues

The three studies of this thesis suffer also from the general limitations of having been conducted in the rail industry only, which limits the external validity of the findings. Even in rail, with the very diverse roles performed by different departments and even companies where on-call work is present (e.g. train drivers) there are limitations to the generalisation of findings. Some external validity can be derived from other research where similar results were found. A number of studies are present in literature where increased anxiety when on-call was also identified (Imbernon et al., 1993; Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988), alongside reduced sleep quantity when on-call (Van Gelder & Kao, 2006), increased sleepiness on days after working on-call (Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988), reduced sleep quality when on-call (Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988), impacts on the well-being of workers and their family life (Imbernon et al., 1993), and decreased mood (Saxena & George, 2005; Wesnes et al., 1997).

8.8.5 Summary

By relying on perceptions, all three studies of this thesis are vulnerable to both recollection bias and potential exaggeration. Participatory bias is also a potential limitation in all three studies as participation in all three was voluntary. As with many studies that focus on specific populations, generalisations of the results of this research should be made with care. Generalisation for on-call work scheduling systems that share the same characteristics can be made but care should be taken regarding the *proximal* on-call system of work.

8.9 Chapter Conclusion

The aim of the thesis, to increase the understanding of on-call scheduling systems of work, was achieved through the three studies performed. To do so each of the objectives of the thesis was investigated and so were the research questions associated with each objective. This chapter presented the main findings associated with each of the objectives and each of the research questions identified for the thesis, and identifies the benefits of each for industry and academia. The creation of the first specific on-call framework and of the first set of on-call management guidelines are two of the most relevant contributions of the work conducted. The limitations of each study (e.g. sample sizes, locations, recollection bias) together with the general limitations associated with the research context (rail operations only, and even in rail, maintenance staff only) were also discussed. The next chapter presents an extended conclusion of these findings and how each of the findings have contributed to the research field of on-call working hours arrangements.

Chapter 9 Conclusion

9.1 Chapter summary

This chapter, the final chapter of this thesis, discusses the contributions of this work to the field of on-call work scheduling systems of work and identifies areas that future work should aim to clarify. The chapter, and the thesis, then concludes by presenting recommendations for future work.

9.2 Contributions

Nine key contributions can be derived from the work conducted for this thesis. This section compiles and discusses each of these.

9.2.1 Contribution 1: Increased understanding of on-call work

On-call work specific available literature makes it clear that the amount of research conducted onto this scheduling system of work and its outcomes is very limited. This is even more relevant regarding *distal* on-call work than *proximal* on-call work as the available literature has focused mainly on the latter. Moreover, European-wide research has shown that on-call work is quickly becoming the most common system of work in use (Eurofound, 2012). This is most likely due to it being a cheaper alternative to other types of work such as shiftwork. This lack of understanding is also found at Network Rail where on-call arrangements are managed locally, and there are no management procedures, rules or regulations. This is a problem that is across the industry as both European and GB based regulations make no mention of on-call work.

The work conducted for this thesis offers further understanding of on-call work through the identification, distinction, and clarification of *proximal* and *distal* types of on-call work and through the identification of different on-call scenarios or phases that have specific influences and are affected by different factors. The ways these factors interact and lead to unwanted outcomes are represented in the framework, which, together with the three studies conducted is one of the main outcomes of the thesis.

The three studies of this thesis and the development of a framework aimed to expand this knowledge both regarding the factors at play on the *distal* on-call scheduling system of work and the relationship between these factors. It must be recognised that, regardless of this research, much work is still required to allow a fuller understanding of the relevant factors that relate to on-call work. Nonetheless, this research offers significant insight into on-call arrangements mainly through the large number of interviews conducted in Study 1.

Section 1.3 Key theoretical areas of interest in Chapter 1 identified the key theoretical areas of interest for this thesis and how these influenced the framework for the work conducted.

The key findings of this work and the contributions to each of these areas of interest are:

- Fatigue Risk Management,

    a. Support found for increased fatigue during an on-call week when compared to when non on-call,

    b. Further support found the association of anxiety in the evening and fatigue in the morning,

    c. Further support found for the association between sleep quality and fatigue,

    d. Further support found for the association between sleep quantity and fatigue,

    e. Increased fatigue when on on-call due to increased anxiety,

    f. Support found for the predicted association between number of callouts when on-call and fatigue,

The summary of these findings not only supports what other on-call research has found (e.g. Murray & Dodds, 2003; Van Gelder & Kao, 2006); that working on-call leads to increased fatigue, but also adds the knowledge that callout specific factors (namely number of callouts) are some of the mechanisms involved in this relationship.

- Callout specific factors,

    a. The longer the callout, the lower the sleep quality,

    b. The higher the number of callouts, the higher the fatigue the morning after,

c. The longer the callout, the longer the amount of time required to get back to sleep,
d. Performance is more compromised when callouts occur when on-call workers are asleep than when still awake,
e. Receiving five to eight callouts during a week when even only 0% to 25% of these occur after going to sleep has the highest impact on fatigue.

Callout specific factors and their relationships with other on-call related factors had yet to be investigated by on-call research. The investigation and findings relating to these in this thesis are probably the greatest contribution of this work to this specific theoretical area.

- Sleep research,
  a. Lower sleep quality when on-call due to anxiety,
  b. The longer the callout, the longer the amount of time required to get back to sleep,
  c. Sleep quality when on-call and receiving callouts is significantly better when callouts are shorter than 10 minutes when compared with longer calls,
  d. Sleep quality is more affected when callouts occur when participants are already asleep

These findings contribute directly to sleep disruption research by finding support for the callout specific factors and sleep outcomes. Anxiety and its impacts on sleep quality and on fatigue had already been hinted at by Torsvall & Akerstedt (1988) and further support was found though the work of this thesis. More than this, further details on the idiosyncrasies of these relationships were also discovered and relate directly to callout specific factors. These represent clear contributions to the field of sleep research and in particular to the field of sleep disruption where such research is novel.

- Well-being,

a. Reduced family life when on-call due to anticipation of callouts, reception of callouts, and sleep disruption of partner,

b. Low levels of satisfaction with on-call work,

c. Low levels of satisfaction with time on-call work leaves for family, self, and for hobbies,

d. Working more than 16h consecutive hours when on-call leads to lower levels of satisfaction with on-call work than working less than 16h,

e. Reduced well-being when required to work on-call on a rostered day off.

As one of the main theoretical areas of interest for this thesis, many well-being related contributions were found. The results of Study 1 in particular clearly describe the level of the impact of on-call work on the well-being of workers and their families. These support the findings of Imbernon et al. (1993) who found that the well-being of the family of on-call staff were also affected by callouts and to those of Heponiemi et al. (2008) who found that satisfaction with on-call work was low.

- Stress, performance, and mood,

    a. High levels of anxiety when on-call (due to anticipation of receiving callouts),

    b. High levels of anxiety throughout the on-call week,

    c. Anxiety and mood found to be significantly worse when on-call than when not on-call,

    d. The higher the anxiety in the evening, the worse the quality of sleep,

    e. The higher anxiety in the evening, the higher fatigue in the morning,

    f. Performance is more compromised when callouts occur between 2400 and 0400 hours,

    g. Performance is more compromised when callouts occur when on-call workers are asleep than when still awake,

The findings found further support to the role of anxiety in on-call work previously hinted at by Torsvall & Akerstedt (1988) who indicated that anxiety when on-call was correlated with low sleep quality and increased fatigue. The relationship between stress and fatigue in shiftwork is a well known one (refer to section 3.5.2 Stress and Fatigue in Chapter 3 for more details) which is supported for on-call work by the findings of this thesis.

Impaired performance when working on-call has been identified by a number of on-call studies, which have found an association between on-call work and declining mood and impaired cognitive performance (Saxena & George, 2005; Wesnes et al., 1997). Sleep disruption research has also identified that sleep fragmentation (e.g. Martin et al., 1996; Murray & Dodds, 2003) leads to performance impairments and so does circadian disruption (e.g. Åkerstedt, 2007; Saxena & George, 2005) and extended wakefulness (e.g. Jewett et al., 1999; Van Dongen, Maislin, et al., 2003). The findings of this thesis support these and go some way to find support for identifying when the most damaging times to be called-out are although the results of the three studies conducted are not in accordance.

Other key findings of the work conducted which are not related directly to these key areas on interest are:

- On-call work is arranged in rosters,
- No clear support found for age and experience to moderate the effects of on-call work,
- Three distinct on-call scenarios or phases.

9.2.2 Contribution 2: The importance of on-call scenarios

The available on-call related literature has solely investigated the on-call scheduling system of work as a whole. The importance and differences identified between the different on-call scenarios or phases has, perhaps, been hinted at by other research (Imbernon et al., 1993) but not formalised or investigated. This thesis, on the other hand, has clearly defined three distinct on-call scenarios and has investigated some of the key factors at play for each. The relationships between these factors and the unwanted outcomes associated with each were also investigated and are presented in a diagrammatic format in the on-call framework. It is important to remember that the scenarios of receiving callouts and responding to callouts were found to be more similar than the stand-by scenario. Nonetheless further risks have been identified when needing to attend site when responding to callouts in comparison to receiving callouts. The key findings for each scenario are:

Stand by

- Influenced by cover arrangements and requirement to maintain normal working hours,
- Influenced by annual leave and rostered days off,
- High levels of anxiety when on-call (due to anticipation of receiving callouts),
- Reduced quality and quantity of sleep due to anxiety,

Receiving callouts

- Reduced sleep quantity,
- Higher levels of anxiety than when not on-call or when on stand-by,
- Callouts that occur after going to sleep have higher impacts on performance,
- Lower well-being of worker and family members,

Attending callouts

- Reduced mood when compared to being on stand-by and receiving callouts,
- Higher fatigue on day after mainly due to travel time to site and reduced sleep quantity.
- Lower well-being of worker and family members,

9.2.3 Contribution 3: New knowledge and emphasis on *distal* on-call working

The available on-call literature although limited, has been mainly focused on *proximal* on-call work with only a few studies focusing on the *distal* type of on-call work (Imbernon et al., 1993; Pilcher & Coplens, 2000). The work of this thesis adds to the knowledge of these studies by exploring the impact and relationships between both factors explored by these studies (anxiety, reduced sleep quality, sleepiness the day after on-call) and factors not explored by these studies (e.g. number, length, and timing of callouts).

9.2.4 Contribution 4: Highlighting key relationships in on-call working

On top of exploring factors not previously investigated by on-call research, the work conducted for this thesis also explored the relationships between these factors. A number of specific relationships were identified not only between factors but also relating these to the on-call scenario in which they occur. One example is the relationship between being on stand-by and the increased anxiety which in turn can lead to reduced quality of sleep. The investigation and identifications of these relationships is a key contribution of this thesis both for academia, by expanding on the knowledge of the relationship between factors, but also for industry by identifying potential key areas of influence for the management of on-call work.

9.2.5 Contribution 5: Framework

Initially developed from the available literature of both on-call work and shiftwork the framework was further developed at each stage of this thesis. As such, it is a key contribution from this thesis as it represents not only the first on-call work framework developed but also one that is based on research. The framework identifies not only the key factors at play but also the relationships between them, acting as an explicit formalisation of Contribution 4. It presents a set of principles or a theory that other researchers can use to guide future research and that industry professionals can use to deliver guidelines on the management of on-call arrangements as has been done in this research.

9.2.6 Contribution 6: On-call management guidance

It is clear that strong business benefits exist for the use of on-call work in industry as the results of the latest European Working Conditions Survey shows (Eurofound, 2012). On-call work, although a relatively new form of providing 24 hour monitoring has already become the most common form of scheduled work across Europe. As such, it cannot be reasonably expected that this type of work will disappear in a near future. Quite the contrary! Working hours researchers must realise this shift in industry and respond by making on-call work the central focus of working hours research. The production of on-call specific guidelines will allow industry to implement sensible risk management policies and actions to start managing this scheduling system of work and can only benefit on-call workers.

9.2.7 Contribution 7: Methods for on-call

Of the methods used in this thesis to investigate the on-call scheduling system of work two are worth mentioning as key contributions for this thesis; the questionnaire and the diary.

The on-call specific questionnaire was developed from a widely used and validated measure – The Standard Shiftwork Index and on railways specific questionnaire REQUEST (also widely used in the railways). It covers many of the on-call specific characteristics and the unwanted consequences of on-call work. Similarly, the diary developed also identifies many of the key factors of importance for all three on-call scenarios from anxiety levels to callout specific details (e.g. time, length, sleep disturbance). Moreover, the diary protocol developed also explored the possibilities of new technology and paves the way for other researchers to develop more integrated and complex diary protocols through the use of mobile telephone applications. Such applications can be of great benefit to investigate not only on-call work but also to other research investigating the blurring of the separation between work and personal life.

9.2.8 Contribution 8: Validation and extension of existing theoretical work

This thesis, although focusing on *distal* on-call work has, nonetheless, found support to the majority of effects identified regarding both *proximal* and *distal* on-call work. The following unwanted effects identified in literature were also found in this research:

- Increased anxiety - initially identified by Torsvall & Akerstedt (1988) on *proximal* on-call work, and also identified by another *proximal* on-call study and a study into *distal* on-call work (Imbernon et al., 1993; Pilcher & Coplens, 2000),
- Reduced sleep quantity when on-call (Van Gelder & Kao, 2006) – identified for on *proximal* on-call resident doctors. This thesis found support for this mainly when callouts occur,
- Increased sleepiness / fatigue on day after working on-call (Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988).
- Decreased sleep quality when on-call (Pilcher & Coplens, 2000; Torsvall & Akerstedt, 1988),

- Impact on the well-being of workers and their family life (Imbernon et al., 1993),
- More turnover intentions and low satisfaction with on-call work (Heponiemi et al., 2008),
- Decreased mood (Saxena & George, 2005; Wesnes et al., 1997).

There were also factors identified in literature that the results of this thesis did not support. Pilcher & Coplens (2000) found that workers reported having more difficulties falling asleep when on-call but no support for increased sleep latency was found. Two studies on *proximal* on-call work have also found cognitive performance to be impaired when on-call (Saxena & George, 2005; Wesnes et al., 1997). On the other hand, a further study investigating these same factors, regarding *proximal* on-call work found no effect on performance (Kiernan et al., 2006). The results of this thesis were also unable to demonstrate a clear relationship between on-call work and performance. As discussed in detail in section 8.5.1 What are the on-call factors that lead to consequences and how do they interact? participants generally stated that performance is not greatly affected but with effects being identified regarding callout timing and numbers, and calls that disrupt sleep.

9.2.9 Contribution 9: Additional theoretical contributions

The work conducted for this thesis also made the following contributions to the field of on-call work that have not been identified in literature:

- Identification of different on-call scenarios which are associated with different unwanted effects and of the factors industry can make use of to reduce the impact into each of these scenarios,
- Further explored the relationship between on-call related factors,
- Assessment of callout specific factors that lead to unwanted consequences - length, timing, and number of callouts,
- Compilation of the first on-call framework where factors and their relationships are represented together with the industrial arrangements and pressures that affect the different on-call arrangements and outcomes,
- Compilation and industry assessment of the first set of on-call work

management guidelines.

9.3 Future research

Regardless of the findings of this thesis there is still much that is unknown about on-call work and additional work is required to further clarify both the factors at play, the relationships between them, and the unwanted effects of on-call work. The limitations of this thesis, mainly regarding the reliance on subjective ratings, can also be mitigated through the use of non-subjective ratings. It is, therefore, recommended that future research make use of less subjective measures such as:

- Actigraphs,
- Electrocardiograms,
- Melatonin and cortisol measurements,

Research protocols where these measures are combined with large data samples would afford a much higher reliability and validity to on-call work research.

It is also important to mention that some of these measures have been already used by on-call studies in the literature whose results were supported by the subjective ratings collected in the studies of this thesis. Torsvall & Akerstedt (1988) for example, used electroencephalogram and electrocardiogram to assess the effects of on-call duties on sleep and found that on-call workers reported both higher degrees of sleepiness during the day following an on-call period and a decrease in sleep quality. Van Gelder & Kao (2006) also present a precedent for the use of actigraphs, where they found a significant increase in napping times on post on-call days vs. non on-call days. Although their use is limited in on-call work, actigraphs are extensively used in sleep research and their usages well documented and validated (e.g. Åkerstedt & Wright, 2009; Ancoli-israel et al., 2003; Haire et al., 2012). In a similar situation are melatonin and cortisol measurements where, although not yet used to investigate on-call work, they are commonly used in sleep and stress related research (e.g. Axelsson, Åkerstedt, Kecklund, Lindqvist, & Attefors, 2003; Caldwell, Caldwell, & Schmidt, 2008; Dahlgren, Kecklund, & Åkerstedt, 2005).

This offers some further support to the methods used in this thesis and to the validity of self reporting scores. The use of these measures together with non-subjective measures of performance and fatigue should also be explored by future research.

This will allow for a better understanding of the effects of on-call work.

To allow for a better understanding of the effects of callout specific factors, future work should make use of available call recording technology to automatically record the callout details (length, time, number). This was initially planned for this thesis but unfortunately Network Rail's mobile telecommunications provider does not keep a record of these (fixed communications are recorded but not mobile ones). A further outcome from such a functionality that should be explored by future research is the recording of the actual callout. This would allow the analysis of the reasons and requirements of the callout, as it must be expected that different incidents lead to different requirements and actions to be taken by on-call workers.

The combination of all these methods will allow for a greater understanding of the impacts of each of the factors and of the interaction between them. For example, an actiwatch would provide more exact data regarding sleep latency, the amount of time required to fall back asleep after a callout, total sleep quantity. This combined with call recording technology would allow the identification of how each of the callout specific factors affect the sleep indicators.

Future work should also aim to explore other expected negative outcomes of on-call work not explored in this work. For example, the impact of on-call work on health and the effects of individual factors such as personality and circadian type. Longitudinal studies into the long term effects of on-call work should also be conducted as it can be expected that similar effects on health to those seen with regards to shiftwork will occur like the development of sleep disorders (Céline Ribet & Derriennic, 1999).

The differences and similarities between *proximal* and *distal* on-call work and between the different on-call arrangements (n days in n days vs. n week in n weeks, vs. other arrangements) should also be explored by future research. Similarly, future work should aim to better understand the informal arrangements for their resilience and potential benefits for the management of on-call related fatigue, stress, and well-being. It must be expected that similar arrangements are in place in other industries as coping mechanisms against the negative outcomes of on-call work.

Future work should also aim to expand on the framework developed. All areas of the framework would greatly benefit from further research. For the researcher in particular, the causal factors associated with the calls themselves, as the main drivers of on-call work, hold the greatest interest. Although the work conducted for this thesis has identified some of the idiosyncrasies and consequences of the impacts of timing, length, and time of call-out, much research is still required to better comprehend the impact of these on the unwanted outcomes of on-call work. A study using both actigraphs and subjective measures would be of great value to the understanding of these factors and the negative impacts that these could bring. It would also be of great value to ensure that all participants would perform their on-call duties during the same week and as such, control for such confounding variables as events occurring in the network during that period, ongoing works, and climatic events that affect the railways.

9.4 The future for industry

For Network Rail the research based guidelines compiled, as one of the contributions of this thesis, are being taken forward into implementation into the company's Fatigue Risk Management System. Through the compilation of more management friendly on-call principles the guidance will be introduced initially to high-level managerial stakeholders in Infrastructure Maintenance with the expectation of quick implementation both into work practices and company standards and regulations. The results and guidance have also been presented to the rail industry as a whole on the 2nd Fatigue Risk Management Forum held by the Rail Safety and Standard Board (one of the UK rail regulators) and were also well received. Here also the work was well received and was in effect recommended for the "IOSH Railway Group Award 2013 for Fatigue Management" and the author has been invited to share the results and produced guidance with the Association of Train Operating Companies (ATOC) and the Institute of Occupational Safety and Health (IOSH). This indicates that the work conducted is both relevant and of great interest across the GB rail industry.

Following the results of this research regarding Infrastructure Maintenance, Network Rail has also shown interest in conducting a similar exercise across the Operations part of the company (the Operations department covers the activities of signalling trains and the management structure associated with this). A diary study using actigraphs together with subjective measures is being discussed at the moment for the Operations side of the company where on-call work is also highly used.

Although rail-centred, the findings of this thesis are cross industry much the same as on-call work is, as the results from the 5th European Working Conditions Survey show (Eurofound, 2012). Regardless of the distinction that can be made between *proximal* and *distal* on-call work many of the unwanted outcomes that were identified in this thesis apply to both types of on-call work. Increased anxiety, reduced sleep quality and sleep quantity, and increased fatigue have been found in both types. Differences between the types and between industries may lie within the number, length, and timing of callouts, and will most definitely differ regarding the requirements of each callout. However, the findings of this work, the on-call framework, and the guidance provided will nonetheless be of great value to all other industries that make use of on-call work.

References

Ahsberg, E., Kecklund, G., Akerstedt, T., & Gamberale, F. (2000). Shiftwork and different dimensions of fatigue. *International Journal of Industrial Ergonomics*, *26*, 457–465.

Åkerstedt, T. (1988). Sleepiness as a Consequence of Shift Work. *Sleep, 11*(1), 17–34.

Åkerstedt, T. (1990). Psychological and psychophysiological effects of shift work. *Scandinavian Journal of Work Environment & Health, 16*, 67–73.

Åkerstedt, T. (1995). Work hours and sleepiness. *Neurophysiologie Clinique*, (25), 367–375.

Åkerstedt, T. (1998). Shift work and disturbed sleep/wakefulness. *Sleep Medicine Reviews*, *2*(2), 117–128.

Åkerstedt, T. (2000). Consensus Statement : Fatigue and accidents in transport operations. *Journal of sleep research*, (9), 395.

Åkerstedt, T. (2005). Shift work and sleep disorders. *Sleep*, *28*(1), 9–11.

Åkerstedt, T. (2006a). Sleepiness and Circadian Rhythm Sleep Disorders. *Sleep Medicine Clinics*, *1*(1), 17–30.

Åkerstedt, T. (2006b). Psychosocial stress and impaired sleep. *Scandinavian Journal of Work, Environment & Health*, *32*(6), 493–501. doi:10.5271/sjweh.1054

Åkerstedt, T. (2007). Altered sleep/wake patterns and mental performance. *Physiology & behavior*, *90*(2-3), 209–18. doi:10.1016/j.physbeh.2006.09.007

Åkerstedt, T., Fredlund, P., Gillberg, M., & Jansson, B. (2002). Work load and work hours in relation to disturbed sleep and fatigue in a large representative sample. *Journal of Psychosomatic Research*, *53*, 585–588.

Akerstedt, T., & Gillberg, M. (1990). Subjective and objective sleepiness in the active individual. *The International journal of neuroscience*, *52*(1-2), 29–37. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2265922

Åkerstedt, T., Kecklund, G., & Gillberg, M. (2007). Sleep and sleepiness in relation to stress and displaced work hours. *Physiology & Behavior*, *92*, 250–255. doi:10.1016/j.physbeh.2007.05.044

Åkerstedt, T., Kecklund, G., Gillberg, M., Lowden, A., & Axelsson, J. (2000). Sleepiness and days of recovery. *Transportation Research Part F: Traffic Psychology and Behaviour*, *3*(4), 251–261. doi:10.1016/S1369-8478(01)00009-2

Åkerstedt, T., Knutsson, A., Westerholm, P., Theorell, T., Alfredsson, L., & Kecklund, G. (2004). Mental fatigue , work and sleep. *Journal of Psychosomatic Research*, *57*, 427–433. doi:10.1016/j.jpsychores.2003.12.001

Åkerstedt, T., & Wright, K. P. (2009). Sleep Loss and Fatigue in Shift Work and Shift Work Disorder. *Sleep Medicine Clinics*, *4*, 257–271. doi:10.1016/j.jsmc.2009.03.001

Allan, C., Loudoun, R., & Peetz, D. (2007). Influences on work/ non-work conflict. *Journal of Sociology*, *43*(3), 219–239. doi:10.1177/1440783307080104

Allesøe, K., Hundrup, Y. A., Thomsen, J. F., & Osler, M. (2010). Psychosocial work environment and risk of ischaemic heart disease in women: the Danish Nurse Cohort Study. *Occupational and environmental medicine*, *67*(5), 318–22. doi:10.1136/oem.2008.043091

Ancoli-israel, S., Cole, R., Alessi, C., Chambers, M., Moorcroft, W., & Pollak, C. P. (2003). The Role of Actigraphy in the Study of Sleep and Circadian Rhythms. *Sleep*, (3), 342–392.

Ansiau, D., Wild, P., Nniezborala, M., Rouch, I., & Marquié, J. (2008). Effects of working conditions and sleep of the previous day on cognitive performance. *Apllied Ergonomics*, *39*, 99–106. doi:10.1016/j.apergo.2007.01.004

Arnedt, J. T., Wilde, G. J., Munt, P. W., & MacLean, a W. (2001). How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accident; analysis and prevention*, *33*(3), 337–44. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11235795

Aschoff, J. (1969). Desynchronization and resynchronization of human circadian rhythms. *Aerospace Medicine*, *40*(8), 844–849.

Asltoghiri, M., & Ghodsi, Z. (2011). Study of the Relation between Sleep Disorder and Depression at Late Stage of Pregnancy. *Procedia - Social and Behavioral Sciences*, *28*, 430–434. doi:10.1016/j.sbspro.2011.11.082

Axelsson, J., Åkerstedt, T., Kecklund, G., Lindqvist, A., & Attefors, R. (2003). Hormonal changes in satisfied and dissatisfied shift workers across a shift cycle. *Journal of applied physiology*, *95*, 2099–105. doi:10.1152/japplphysiol.00231.2003

Baker, K., & Olson, J. (1994). Work Practices , Fatigue , and Nuclear Power Plant Safety Performance. *Human Factors*, *36*(2), 244–257.

Balkin, T. J., & Badia, P. (1988). Relationship between sleep inertia and sleepiness: Comulative effects of fours nights of sleep disruption/restriction on performance following abrupt nocturnal awakenings. *Biological Psychology*, *27*, 245–258.

Balkin, T. J., Rupp, T., Picchioni, D., & Wesensten, N. J. (2008). Sleep loss and sleepiness: current issues. *Chest*, *134*(3), 653–60. doi:10.1378/chest.08-1064

Barnes-farrell, J. L., Davies-schrils, K., Mcgonagle, A., Walsh, B., Di Milia, L., Fisher, F., … Tepas, D. (2008). What aspects of shiftwork influence off-shift well-being of healthcare workers ? *Apllied Ergonomics*, *39*, 589–596. doi:10.1016/j.apergo.2008.02.019

Baron, R., & Kenny, D. (1986). The Moderator-Mediator variable distinction in Social Psychology research. *Journal of Personality and Social Psychology*, (51), 1173 – 1182.

Barton, J., Smith, L., Totterdell, P., Spelten, E., & Folkard, S. (1993). Does individual choice determine shift system acceptability? *Ergonomics*, *36*(1-3), 93–99.

Barton, J., Spelten, E., Totterdell, P., Folkard, S., & Costa, G. (1995). The standard Shiftwork Index: A battery of questionnaires for assessing shiftwork related problems. *Work & Stress*, *9*(1), 4 – 30.

Baulk, S. D., Kandelaars, K. J., Lamond, N., Roach, G. D., Dawson, D., & Fletcher, A. (2007). Does variation in workload affect fatigue in a regular 12-hour shift system ? *Sleep and Biological Rhythms*, *5*, 74–77. doi:10.1111/j.1479-8425.2006.00249.x

Belenky, G., Wesensten, N. J., Thorne, D. R., Thomas, M. L., Sing, H. C., Redmond, D. P., … Balkin, T. J. (2003). Patterns of performance degradation and restoration during sleep restriction and subsequent recovery : a sleep dose-response study. *Journal of sleep research*, *12*, 1–12.

Benca, R. M., William, H., Thisted, R. A., & Gillin, J. C. (1992). Sleep and Psychiatric Disorders. *Sleep and Psychiatric Disorders*, *49*(8), 651–670.

Bendak, S. (2003). 12-h workdays : current knowledge and future directions. *Work & Stress*, *17*(4), 321–336. doi:10.1080/02678370310001643478

Bennett, L. S., Barbour, C., Langford, B., Stradling, J. R., & Davies, R. J. (1999). Health status in obstructive sleep apnea: relationship with sleep fragmentation and daytine sleepiness, and effects of continuous positive airway pressure treatment. *American journal of respiratory and critical care medicine*, *159*(6), 1884–90. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10351935

Benzécri, J. P. (1977). Sur l'analiyse des tableaux binaires associés a une correspondance multiple. *Les Cahiers de l'analyse des Données*, *2*, 55 – 71.

Bianchi, S. M. (2011). Family Change and Time Allocation in American Families. *The ANNALS of the American Academy of Political and Social Science*, *638*(1), 21–44. doi:10.1177/0002716211413731

Billiard, M., & Dauvilliers, Y. (2004). Disorders of the sleep/wake circadian rhythm. *EMC - Neurologie*, *1*(3), 246–253. doi:10.1016/j.emcn.2004.03.004

Boggild, H., & Knutsson, A. (1999). Shift work, risk factors and cardiovascular disease. *Scandinavian Journal of Work, Environment & Health*, *25*(2), 85–99. doi:10.5271/sjweh.410

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary Methods: Capturing Life as it is Lived. *Annual Review Psychology*, *54*, 579–616. doi:10.1146/annurev.psych.54.101601.145030

Bonnet, M. (1985). Effect of Sleep Disruption on Sleep , Performance , and Mood. *Sleep*, *8*, 11–19.

Bonnet, M. (1989). Infrequent Periodic Sleep Disruption : Effects on Sleep , Performance and Mood. *Physiology & Behavior*, *45*, 1049–1055.

Bonnet, M., & Arand, D. (2003). Clinical effects of sleep fragmentation versus sleep deprivation. *Sleep Medicine Reviews*, *7*(4), 297–310.

Borbély, A. (1982). A two process model of sleep regulation. *Human Neurobiology*, *3*(1), 195–202.

Boscolo, P. (2009). Effetto dello stress occupazionale e dell ' insicurezza di inserimento lavorativo sull ' efficienza del sistema immunitario. *Giornale Italiano de Medicina del Lavoro ed Ergonomia,, 31*(3), 277–280.

British Psychological Society, B. (2009). *Code of ethics and conduct*. Leicester.

Brown, R., & Thorsteinsson, E. (2009). Stressful life-events and fatigue in a nonclinical sample. *Journal of Nervous and Mental Disease*, *197*(9), 707–710.

Brown, S. A., Kunz, D., Dumas, A., Westermark, P. O., Vanselow, K., Tilmann-wahnschaffe, A., … Kramer, A. (2008). Molecular insights into human daily behaviour. *National Academy of Sciences, 105*(5), 1602–1607.

Bryant, P. A., Trinder, J., & Curtis, N. (2004). Sick and tired: Does sleep have a vital role in the immune system? *Nature reviews. Immunology*, *4*(6), 457–467. doi:10.1038/nri1369

Burgard, S. A., & Ailshire, J. A. (2009). Putting Work to Bed : Stressful Experiences on the Job and Sleep Quality. *Journal of Health and Social Behavior*, *50*(4), 476–492. doi:10.1177/002214650905000407

Caldwell, J. A., Caldwell, J. L., & Schmidt, R. M. (2008). Alertness management strategies for operational contexts. *Sleep Medicine Reviews*, *12*, 257–273. doi:10.1016/j.smrv.2008.01.002

Cao, C. G. L., Weinger, M. B., Slagle, J., Zhou, C., Ou, J., Gillin, S., … Mazzei, W. (2008). Differences in day and night shift clinical performance in Anesthesiology. *Human Factors, 2*, 276–290. doi:10.1518/001872008X288303

Carley, M. (2006). Working Time Developments. *European Foundation for the Improvement of Living and Working Conditions*. Retrieved from http://www.eurofound.europa.eu/eiro/studies/tn0705019s/tn0705019s.htm

Carskadon, M., & Dement, W. (1994). Normal human sleep: an overview. *Principles and practice of sleep medicine*, *18*, 16–25.

Charlton, S., & Baas, P. (2001). Fatigue,work-rest cycles, and psychomotor performance of New Zealand truck drivers. *New Zealand Journal of Psychology*, *30*(1), 32–39.

Chen, M. (1986). The epidemiology of self-perceived fatigue among adults. *Preventive Medicine*, *15*(1), 74–81.

Chu, J., & Richdale, A. (2009). Sleep quality and psychological wellbeing in mothers of children with developmental disabilities. *Research in Developmental Disabilities, 30*(6), 1512–1522.

Cinamon, R. G. (2006). Anticipated Work-Family Conflict : Effects of Gender , Self-Efficacy , and Family Background. *The Career Development Quarterly*, *54*(3), 202–215.

Colligan, M., & Rosa, R. R. (1990). Shiftwork effects on social and family life. *Occupational Medicine*, *2*, 315–322.

Comperatore, C. A., & Krueger, G. P. (1990). *Circadian Rhythm Desynchronosis, Jet Lag, Shift Lag, and Coping Strategies*.

Cooper, C. L., Rout, U., & Faragher, B. (1989). Mental health , job satisfaction , and job stress among general practitioners. *British Medical Journal, 298*, 366–370.

Costa, G. (1997). Shiftwork: The problem. *Chronobiology International*, *14*(2), 89–98.

Costa, Giovanni. (1995). Occupational stress and stress prevention in air traffic control. *Office*. Geneva.

Costa, Giovanni. (1996). The impact of shift and night work on health. *Applied Ergonomics, 27*, 9–16.

Costa, Giovanni. (2003). Shift work and occupational medicine : an overview. *Occupational Medicine*, *53*, 83–88. doi:10.1093/occmed/kqg045

Costa, Giovanni, & Di Milia, L. (2008). Aging and shift work: a compleax problem to face. *Chronobiology International*, *25*, 165–181.

Costa, Giovanni, & Sartori, S. (2007). Ageing, working hours and work ability. *Ergonomics*, *50*(1914-1930).

Coucher, I. (2010). Ian’s blog. *Ian’s blog*. Retrieved from Network rail’s internal communication website Connect

Culpepper, L., Schwartz, J. R. L., & Thorpy, M. J. (2010). The social and economic burden of shift-work disorder. *Journal of Family Practice*, *59*(1), 3–31.

Dahlgren, A., Kecklund, G., & Åkerstedt, T. (2005). Different levels of work-related stress and the effects on sleep, fatigue and cortisol. *Scandinavian Journal of Work, Environment & Health*, *31*(4), 277–285. doi:10.5271/sjweh.883

Dawson, D., & Mcculloch, K. (2005). Managing fatigue : It’s about sleep. *Sleep Medicine Reviews, 9*, 365–380. doi:10.1016/j.smrv.2005.03.002

Dawson, D., & Reid, K. (1997). Fatigue, alcohol and performance impairment. *Nature, 388*(6639), 235. doi:10.1038/40775

De Croon, E., Sluiter, J., & Fringsdresen, M. (2003). Need for recovery after work predicts sickness absence. A 2-year prospective cohort study in truck drivers. *Journal of Psychosomatic Research*, *55*(4), 331–339. doi:10.1016/S0022-3999(02)00630-X

De Gucht, V., & Guzman, M. (2004). Work stress and negative affectivity as determinants of fatigue in nurses. *Psychology and Health*, *19*(Supplement), 40–41.

De Raeve, L., Kant, I., Jansen, N. W. H., Vasse, R. M., & Van den Brandt, P. (2009). Changes in mental health as a predictor of changes in working time arrangements and occupational mobility : Results from a prospective cohort study. *Journal of Psychosomatic Research*, *66*(2), 137–145. doi:10.1016/j.jpsychores.2008.05.007

Deary, I. J., & Tait, R. (1987). Effects of sleep disruption on cognitive performance and mood in medical house officers. *British medical journal (Clinical research ed.)*, *295*(6612), 1513–6. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1248664&tool=pmcentrez&rendertype=abstract

Della Rocco, P., Comperatore, C., Caldwell, L., & Cruz, C. (2000). *The Effects of Napping on Night Shift Performance*. *Security*.

Dembe, A., Erickson, J., Delbos, R., & Banks, S. (2005). The impact of overtime and long work hours on occupational injuries and illnesses: new evidence from the United States. *Occupational and Environmental Medicine*, *62*, 588=597. doi:10.1136/oem.2004.016667

Dinges, D, & Kribbs, N. (1991). Peroforming while sleepy: Effects of experimentallly-induced sleepiness. In T. Monk (Ed.), *Sleep, Sleepiness, and Performance* (pp. 97–128). John Wiley and sons Ltd.

Dinges, David, Neri, D., & Rosekind, M. (1997). *Sustained carrier operations: Sleep loss, performance, and fatigue countermeasures*. *Sleep (Rochester)* (pp. 1–21).

Doi, Y., Minowa, M., & Tango, T. (2003). Impact and correlates of poor sleep quality in Japanese white-collar employees. *Sleep*, *26*(4), 467–71. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12841374

Dorrian, J., Baulk, S. D., & Dawson, D. (2011). Work hours, workload, sleep and fatigue in Australian Rail Industry employees. *Applied ergonomics*, *42*(2), 202–9. doi:10.1016/j.apergo.2010.06.009

Drake, C., Roehrs, T., Breslau, N., Johnson, E., Jefferson, C., Scofield, H., & Roth, T. (2010). The 10-Year Risk of Verified Motor Vehicle Crashes in Relation to Physiologic Sleepiness. *Sleep*, *33*(6), 745–752.

Duclos, A., Peix, J., Colin, C., Kraimps, J., Touzet, S., & Lifante, J. (2012). Influence of experience on performance of individual surgeons in thyroid surgery : prospective cross sectional multicentre study. *British Medical Journal*, *8041*, 1–11. doi:10.1136/bmj.d8041

Edéll-Gustafsson, U. M. (2002). Sleep quality and responses to insufficient sleep in women on different work shifts. *Journal of clinical nursing*, *11*(2), 280–288. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11903728

Edéll-Gustafsson, U. M., Kritz, E. I. K., & Bogren, I. K. (2002). Self-reported sleep quality, strain and health in relation to perceived working conditions in females. *Scandinavian journal of caring sciences*, *16*(2), 179–87. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12000672

Ekstedt, M., Söderström, M., & Akerstedt, T. (2009). Sleep physiology in recovery from burnout. *Biological psychology*, *82*(3), 267–73. doi:10.1016/j.biopsycho.2009.08.006

Ekstedt, M., Söderström, M., Akerstedt, T., Nilsson, J., Søndergaard, H.-P., & Aleksander, P. (2006). Disturbed sleep and fatigue in occupational burnout. *Scandinavian Journal of Work, Environment & Health*, *32*(2), 121–131. doi:10.5271/sjweh.987

Eriksen, C. A., & Kecklund, G. (2007). Sleep, sleepiness and health complaints in police officers: the effects of a flexible shift system. *Industrial health*, *45*(2), 279–88. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17485872

Eriksson, A., Ekbom, A., Granath, F., Hilding, A., Efendic, S., & Ostenson, C. (2008). Psychological distress and risk of pre-diabetes and Type 2 diabetes in a prospective study of Swedish middle-aged men and women. *Diabetic medicine : a journal of the British Diabetic Association*, *25*(7), 834–842. doi:10.1111/j.1464-5491.2008.02463.x

Eurofound. (2012). *5th European Working Conditions Survey*. Luxembourg.

EUROSTAT. (2012). *"Passenger transport statistics" - Statistics Explained*. Retrieved from http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Passenger_transport_statistics#

Feldman Barret, L., & Barret, D. (2001). An introduction to computerized experience sampling in psychology. *Social Science Computer Review*, *19*, 175–185.

Fletcher, A., & Dawson, D. (2001). Field-based validations of a work-related fatigue model based on hours of work. *Transportation Research Part F: Psychology and Behaviour*, *4*, 75–88.

Folkard, S. (1996). Effects on performance efficiency. In W. Coquhoun, G. Costa, S. Folkard, & P. Knauth (Eds.), *Shiftwork: Problems and Solution* (1st ed.). Frankfurt: Peter Lang.

Folkard, S., & Hill, J. (2002). *Shiftwork: Body Rhythm and Social Factors*. (P. Warr, Ed.) (5th ed.). London: Penguin.

Folkard, S., & Tucker, P. (2003). Shift work, safety and productivity. *Occupational Medicine*, *53*(2), 95–101. doi:10.1093/occmed/kqg047

Friesen, L. D., Vidyarthi, A. R., Baron, R. B., & Katz, P. P. (2008). Factors associated with intern fatigue. *Journal of general internal medicine*, *23*(12), 1981–1986. doi:10.1007/s11606-008-0798-3

Gaba, D., & Howard, S. (2002). Fatigue amongst clinitians and the safety of patients. *New England Journal of Medicine*, *347*(16), 1249–1255.

Gamble, K. L., Motsinger-Reif, A. a, Hida, A., Borsetti, H. M., Servick, S. V, Ciarleglio, C. M., … Johnson, C. H. (2011). Shift work in nurses: contribution of phenotypes and genotypes to adaptation. *PloS one*, *6*(4), e18395 –. doi:10.1371/journal.pone.0018395

Gawron, V. J., French, J., & Funke, D. (2001). An overview of fatigue. In P. Hancock & P. Desmond (Eds.), *Stress, Workload and Fatigue* (pp. 581–594). Mahwah.

Geiger-brown, J., Muntaner, C., Lipscomb, J., & Trinkoff, A. (2004). Demanding work schedules and mental health in nursing assistants working in nursing homes. *Work & Stress*, *18*(4), 292–304. doi:10.1080/02678370412331320044

Gillberg, M., Kecklund, G., Goransson, B., & Akerstedt, T. (2003). Operator performance and signs of sleepiness during day and night work in a simulated thermal power plant. *International Journal of Industrial Ergonomics*, *31*, 101–109.

Gold, D. R., Rogacz, S., Bock, N., Tosteson, T. D., Baum, T. M., Speizer, F. E., & Czeisler, C. A. (1992). Rotating Shift Work , Sleep , and Accidents Related to Sleepiness in Hospital Nurses. *American Journal of Public Health*, *82*(7), 1011–1014.

Goldberg, D. (1972). *The detection of Psychiatric illness by questionnaire*. Oxford: Oxford University Press.

Golden, L., & Wiens-tuers, B. (2006). To your happiness ? Extra hours of labor supply and worker well-being. *The Jounal of Socio-Economics*, *35*, 382–397. doi:10.1016/j.socec.2005.11.039

Goyal, D., Gay, C., & Lee, K. (2007). Patterns of Sleep Disruption and Depressive Symptoms in New Mothers. *Journal of Perinatal & Neonatal Nursing:*, *21*(2), 123–129.

Goyal, D., Gay, C., & Lee, K. (2009). Fragmented maternal sleep is more strongly correlated with depressive symptoms than infant temperament at three months postpartum. *Archive of Womens Mental Health*, *12*, 229–237. doi:10.1007/s00737-009-0070-9

Grandey, A. A., & Cropanzano, R. (1999). The Conservation of Resources Model Applied to Work – Family Conflict and Strain. *Journal of Vocational Behaviour*, *54*, 350–370.

Greenacre, M. J. (1984). *Theory and applications of correspondance analisys ;* London: Academic Press.

Haines III, V. Y., Marchand, A., Rousseau, V., & Demers, A. (2008). The mediating role of work-to-family conflict in the relationship between shiftwork and depression. *Work & Stress*, *22*(4), 341–356. doi:10.1080/02678370802564272

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate Data Analysis*. *New Jersey* (6th ed.). Prentice Hall.

Haire, J. C. L., Ferguson, S. A., Tilleard, J. D., Negus, P., Dorrian, J., & Thomas, M. J. (2012). Effect of working consecutive night shifts on sleep time, prior wakefulness, perceived levels of fatigue and performance on a psychometric test in emergency registrars. *Emergency Medicine Australasia*, *24*, 251–259. doi:10.1111/j.1742-6723.2012.01533.x

Hakola, T., & Härmä, M. (2001). Evaluation of a fast forward rotating shift schedule in the steel industry with a special focus on ageing and sleep. *Journal of Human Ergology*, *30*(1-2), 315–319. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14564901

Hall, J., Francis II, R., Hammerschimidt, J., Goglia, J., & Black, J. (1999). *Evaluation of U . S . Department of Transportation Efforts in the 1990s to Address Operator Fatigue*.

Harma, M., Sallinen, R., Ranta, R., Mutanen, P., Muller, K., Härmä, M., … Müller, K. (2002a). The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers. *Journal of sleep research*, *11*(2), 141–151. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12028479

Harma, M., Sallinen, R., Ranta, R., Mutanen, P., Muller, K., Härmä, M., … Müller, K. (2002b). The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers. *Journal of sleep research*, *11*(2), 141–151. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12028479

Harma, Mikko. (1996). Ageing , physical fitness and shiftwork tolerance. *Applied Ergonomics*, *27*(I), 25–29.

Harrington, J. M. (2001). Health effects of shift work and extended hours of work. *Occupational and Environmental Medicine*, *58*, 68–72.

Hayes, N. (2000). *Doing Psychological Research Gathering and analysing data*. (Open University, Ed.). New York: McGraw-Hill.

Hendry, J., & Seidl, D. (2003). The Structure and Significance of Strategic Episodes : Social Systems Theory and the Routine Practices of Strategic Change. *Journal of Management Studies*, (January).

Heponiemi, T., Kouvonen, H., Vanska, J., Halila, H., Sinervo, T., Kivimaki, M., & Elovainio, M. (2008). Effects of active on-call hours on physicians turnover intentions and well-being. *Scandinavian Journal of Work Environment & Health*, *34*(5), 356–363. doi:10.5271/sjweh.1278

Hidden, A. (1989). *Investigation into the Clapham Junction Railway Accident*.

Hofer-Tinguely, G., Achermann, P., Landolt, H., Regel, S. J., Retey, J., Durr, R., … Gottselig, J. M. (2005). Sleep inertia : performance changes after sleep , rest and active waking. *Cognitive Brain Research*, *22*, 323–331. doi:10.1016/j.cogbrainres.2004.09.013

Horne, J. (2012). Working throughout the night : Beyond “ sleepiness ” – impairments to critical decision making. *Neuroscience and Biobehavioral Reviews*, (36), 2226 –2231.

Hyyppa, M., & Kronhollm, E. (1989). Quality of sleep and chronic illnesses. *Journal of Clinical Epidemiology*, *42*(7), 633–638.

Imbernon, E., Warret, G., Christine, R., Chastang, J.-F., & Goldberg, M. (1993). Effect of on-call on health and well-being of on-call shifts. An epidemiologic study in the French National Electricity and Gas supply company. *Journal of Occupational Medicine*, 1131 – 1137.

Jansen, N. W. H., van Amelsvoort, L. G. P. M., Kristensen, T. S., van den Brandt, P. a, & Kant, I. J. (2003). Work schedules and fatigue: a prospective cohort study. *Occupational and environmental medicine*, *60 Suppl 1*(Suppl I), i47–53. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1765732&tool=pmcentrez&rendertype=abstract

Janssen, N., & Nijhuis, F. (2004). Acute and chronic job stressors among ambulance personnel: predictors of health symptoms. *Journal of Occupational and Environmental Medicine*, *46*(9), 866–875.

Jay, S., Dawson, D., Ferguson, S. A., & Lamond, N. (2008). Driver fatigue during extended rail operations. *Applied Ergonomics*, *39*, 623–629. doi:10.1016/j.apergo.2008.01.011

Jewett, M. E., Wyatt, J. K., Ritz-De Cecco, a, Khalsa, S. B., Dijk, D. J., & Czeisler, C. a. (1999). Time course of sleep inertia dissipation in human performance and alertness. *Journal of sleep research*, *8*(1), 1–8. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10188130

Kaida, Akerstedt, T., Kecklund, G., Nilsson, J. P., & Axelsson, J. (2007). Use of subjective and physiological indicators of sleepiness to predict performance during a vigilance task. *Industrial Health*, *45*(4), 520–526. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17878623

Kaida, K., Takahashi, M., Akerstedt, T., Nakata, A., Otsuka, Y., Haritani, T., & Fukasawa, K. (2006). Validation of the Karolinska sleepiness scale against performance and EEG variables. *Clinical Neurophysiology*, *117*, 1574–1581. doi:10.1016/j.clinph.2006.03.011

Kallus, W., Boucsein, W., & Spanner, N. (2009). Eight- and twelve-hour shifts in Austrian rail traffic controllers : a psychophysiological comparison. *Psychology Science Quarterly*, *51*(3), 283–297.

Kecklund, G. (2005). Long work hours are a safety risk - causes and practical legislative implications. *Scandinavian Journal of Work Environment & Health*, *31*(5), 81–84.

Kenyon, T. A. G., Gluesing, R. E., White, K. Y., Dunkel, W. L., & Burlingame, B. L. (2007). On Call : Alert or Unsafe ? A Report of the AORN On-CalL Electronic Task Force. *Aorn Journal*, *86*(4), 630–639.

Kerkhof, G., & Van Dongen, H. P. A. (2010). *Human Sleep and Cognition* (First.). New York: Elsevier.

Kiernan, M., Civetta, J., Bartus, C., & Walsh, S. (2006). 24 Hours on-Call and Acute Fatigue No Longer Worsen Resident Mood Under the 80-Hour Work Week Regulations. *Current surgery*, *63*(3), 237–241. doi:10.1016/j.cursur.2006.03.002

Knauth, P. (1996). Designing better shift systems. *Ergonomics*, *27*(1), 39–44.

Knauth, P., & Hornberger, S. (2003). Preventive and compensatory measures for shift workers. *Occupational Medicine*, *53*, 109–116. doi:10.1093/occmed/kqg049

Knutson, K. L., Spiegel, K., Penev, P., & Van Cauter, E. (2007). The metabolic consequences of sleep deprivation. *Sleep medicine reviews*, *11*(3), 163–178.

Knutsson, A. (2003). Health disorders of shift workers. *Occupational Medicine*, *53*(2), 103–108. doi:10.1093/occmed/kqg048

Knutsson, A., & Boggild, H. (2000). Shiftwork and Cardiovascular disease: review of disease mechanisms. *Reviews on Environmental Health, 15,* 359–372.

Kong, T. (2008). Basic Science Review on Circadian Rhythm Biology and Circadian Sleep Disorders. *Annals Academy Medicine*, *37*, 662–668.

Ku, C.-H., & Smith, M. J. (2010). Organisational factors and scheduling in locomotive engineers and conductors: Effects on fatigue, health and social well-being. *Applied ergonomics*, *41*(1), 62–71. doi:10.1016/j.apergo.2009.04.006

Kuhn, G. (2001). Circadian rhythm, shift work, and emergency medicine. *Annals of emergency medicine*, *37*(1), 88–98. doi:10.1067/mem.2001.111571

Kundi, M., Koller, M., Stefan, H., Lehner, L., Kaindlsdorfer, S., & Rottenbucher, S. (1995). Attitudes of nurses towards 8-h and 12-h shift systems. *Work & Stress*, *9*, 134–139.

Lee, K. A. (1998). Alterations in sleep during pregnancy and postpartum: a review of 30 years of research. *Sleep Medicine Reviews*, *2*(4), 231–242.

Leung, A. W. S., Chan, C. C. H., & He, J. (2004). Structural stability and reliability of the Swedish occupational fatigue inventory among Chinese VDT workers. *Applied ergonomics*, *35*(3), 233–41. doi:10.1016/j.apergo.2004.02.004

Levine, B., Roehrs, T., Stepanski, E., Zorick, F., & Roth, T. (1987). Fragmenting sleep diminishes its recuperative value. *Sleep*, *10*(6), 590–9. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3432859

Lida, M., Shrout, P., Laurenceau, J.-P., & Bolger, N. (2012). Using Diary Methods In Psychological Research. In *APA Handbook of Research Methods in Psychology* (pp. 277–305).

Lim, A., Yu, L., Costa, M., Eurgans, S., Buchman, A., Bennet, D., & Saper, C. (2012). Increased fragmentation of rest-activity patterns is associated with a characteristic pattern of cognitive impairment in older individuals. *Sleep*, *35*(05), 633–640.

Lockley, S., Barger, L., Ayas, N., Rothschild, J., Czeisler, C., & Landrigan, C. (2007). Effects of healthcare providers work hours and sleep deprivation on safety and performance. *Joint Commission Journal on Quality and Patient Safety*, *33*(11), 7–18.

Loudoun, R. (2008). Balancing shiftwork and life outside of work: Do 12h shifts make a difference? *Applied Ergonomics*, *39*(5), 572–579. doi:10.1016/j.apergo.2007.12.004

Lyznicki, J. M., Doege, T. C., Davis, R. M., & Williams, M. (1998). Sleepiness , Driving , and Motor Vehicle Crashes. *JAMA: The Journal Of The American Medical Association*, *279*(23), 1908–1913.

Marcil, I., & Vencent, A. (2000). *Fatigue in Air Traffic Controllers: Lieterature Review*. *Public Works* (Vol. 2000).

Martin, S., Engleman, H., Deary, I., & Douglas, N. (1996). The effect of sleep fragmentation on daytime function. *American journal of respiratory and critical care medicine*, *153*(4), 1328–1332.

Mason, J. (1975). A historical view of of the field of stress Part II. *Journal of Human Stress*, *1*, 22–36.

Matthews, G., & Desmond, P. A. (1998). Personality and multiple dimensions of task-induced a study of simulated driving fatigue : *Personality and Individual Differences*, *25*, 443–458.

Matthews, R. A., Priore, R. E. Del, Acitelli, L. K., & Barnes-farrell, J. L. (2006). Work-to-Relationship Conflict : Crossover Effects in Dual-Earner Couples. *Journal of Occupational Health Psychology*, *11*(3), 228–240. doi:10.1037/1076-8998.11.3.228

May, J. F., & Baldwin, C. L. (2009). Driver fatigue : The importance of identifying causal factors of fatigue when considering detection and countermeasure technologies. *Transportation Research Part F: Psychology and Behaviour*, *12*(3), 218–224. doi:10.1016/j.trf.2008.11.005

McDonald, N. (1989). Fatigue and Driving. *Alcohol, Drugs, and Driving*, *5*, 185–191.

McGuffog, M., Turner, C., & Stone, B. (2004). *T059 Human factors study of fatigue and shift work Appendix 1: Working patterns of train drivers - Implications for fatigue and safety*.

Mcnamara, S. G., Grunstein, R. R., & Sullivan, C. E. (2006). Obstructive sleep apnoea. *Thorax*, *48*, 754–764.

Melchior, M., Caspi, A., Milne, B., Danese, A., Poulton, R., & Moffitt, T. (2007). Work stress precipitates depression and anxiety in young, working women and men. *Psychological Medicine*, *37*(8), 1119–1129.

Miccoli, L., Versace, F., Koterle, S., & Cavallero, C. (2008). Comparing sleep-loss sleepiness and sleep inertia: lapses make the difference. *Chronobiology International*, *25*(5), 725–744. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18780200

Michielsen, H. J., Vries, J. De, Heck, G. L. Van, Vijver, F. J. R. Van De, & Sijtsma, K. (2004). Examination of the Dimensionality of Fatigue The Construction of the Fatigue Assessment Scale (FAS). *European Journal of Psychological Assessment*, *20*(1), 39–48. doi:10.1027//1015-5759.20.1.39

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook*. (S. Publications, Ed.)*Thousand Oaks* (Vol. 2nd, p. 352). Sage. Retrieved from http://www.loc.gov/catdir/enhancements/fy0655/93041204-d.html

Milia, L., Bohle, P., Loudoun, R., & Pisarski, A. (2008). Contemporary research findings in shiftwork. *Applied Ergonomics*, *39*, 539–540. doi:10.1016/j.apergo.2008.02.021

Mitchell, R. J., & Williamson, a M. (2000). Evaluation of an 8 hour versus a 12 hour shift roster on employees at a power station. *Applied ergonomics*, *31*(1), 83–93. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10709754

Miyasite, A., Fukuda, K., & Inugami, M. (1989). Effects of sleep interruption on REM-NREM cycle in nocturnal human sleep. *Electroencephalography and Clinical Neurophysiology*, *73*, 107–116.

Morin, C. M., Rodrigue, S., & Ivers, H. (2003). Role of Stress , Arousal , and Coping Skills in Primary Insomnia. *Psychosomatic Medicine*, *65*(2), 259–267. doi:10.1097/01.PSY.0000030391.09558.A3

Morrow, P. C., & Crum, M. R. (2004). Antecedents of fatigue, close calls, and crashes among commercial motor-vehicle drivers. *Journal of safety research*, *35*(1), 59–69. doi:10.1016/j.jsr.2003.07.004

Murray, D., & Dodds, C. (2003). The effect of sleep disruption on performance of anaesthetists--a pilot study. *Anaesthesia*, *58*(6), 520–5. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12846614

Nabe-Nielson, K., Quist, H., Garde, A., & Aust, B. (2011). Shiftwork and changes in health behaviours. *Journal of Occupational and Environmental Medicine*, *53*(12), 1413–1417.

Nag, P. K., & Patel, V. G. (1998). Work accidents among shiftworkers in industry. *International Journal of Industrial Ergonomics*, *21*, 275–281.

Natale, V., & Alzani, A. (2001). Additional validity evidence for the composite scale of morningness. *Personality and Individual Differences*, *30*, 293–301.

Natale, V., & Martoni, M. (2003). Effects of circadian typology on sleep – wake behavior of air traffic controllers. *Psychiatry and Clinical Neurosciences*, *57*, 539–541.

Neri, D., Oyung, R., Colletti, L., Mallis, M., Tam, P., & Dinges, D. F. (2002). Controlled breaks as a fatigue countermeasure on the flight deck. *Aviation Space Environmental Medicine*, *73*(7), 654–664.

Nesthus, T., Cruz, C., Boquet, A., Detwiler, C., Holcomb, K., & Della Rocco, P. (2001). *Circadian temperature rhythms in clockwise and counter-clockwise rapidly rotating shift schedules. Journal of Human Ergology* (Vol. 30, pp. 245–249).

Nicol, A.-M., & Botterill, J. S. (2004). On-call work and health: a review. *Environmental Health*, *3*(1), 15.

Nordin, M., & Knutsson, A. (2001). Sleepiness and recovery in schedule change and the eighty-four hour workweek. *Journal of Human Ergology, 30*, 143–147.

ORR. (2006). *Managing fatigue in safety critical work Railways and Other Guided Transport Systems (Safety) Regulations*. *Regulation*.

Paoli, P., & Merllié, D. (2000). *Third European survey on working conditions 2000*. *AmJCardiol* (Vol. 64, p. 3I–9I). Office for Official Publications of the European Communities. Retrieved from http://www.eurofound.europa.eu/pubdocs/2001/21/en/1/ef0121en.pdf

Parent-Thirion, A., Macías, E. F., Hurley, J., & Vermeylen, G. (2007). *Fourth European Working Conditions Survey*. (Conditions, Ed.)*Context*. European Foundation for the Improvement of Living and Working Conditions. Retrieved from http://www.eurofound.europa.eu/pubdocs/2006/98/en/2/ef0698en.pdf

Perry-Jenkins, M., Goldberg, A., Pirce, C., & Sayer, A. (2007). Shift Work , Role Overload , and the Transition to Parenthood. *Journal of Marriage and the Family*, *69*, 123–138.

Philip, P., Sagaspe, P., Moore, N., Taillard, J., Guilleminault, C., & Bioulac, B. (2005). Fatigue , sleep restriction and driving performance. *Accident Analysis and Prevention*, *37*, 473–478. doi:10.1016/j.aap.2004.07.007

Phillips, M. (2009). Of owls, larks and alarm clocks. *Nature*, *458*, 2006–2008.

Phillipson, E. a, Bowes, G., Sullivan, C. E., Woolf, G. M., Philipson, E., & Sulivan, C. (1980). The influence of sleep fragmentation on arousal and ventilatory responses to respiratory stimuli. *Sleep*, *3*(3-4), 281–288. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7221337

Pilcher, & Coplens. (2000). Work / rest cycles in railroad operations : effects of shorter than 24-h shift work schedules and on-call schedules on sleep. *Ergonomics*, *43*(5), 573–589.

Pilcher, J., Ginter, D., & Sadowsky, B. (1997). Sleep quality versus sleep quantity: Relationships betweem sleep and measures of health, well-being and sleepiness in college students. *Journal of Psychosomatic Research*, *42*(6), 583–596.

Pilcher, J., Lambert, B., & Huffcutt, A. (2000). Differential Effects of Permanent and Rotating Shifts on Self-Report Sleep Length : A Meta-Analytic Review. *Sleep*, *23*(2), 1–9.

Pilcher, J., Popkin, S., Adkins, K., & Roether, L. (2005). Self-Report Naps in Irregular Work Schedules. *Industrial Health*, *43*, 123–128.

Pinel, P. J. (1992). *Biopsychology*. Allyn & Bacon.

Pires, M. L. N., Teixeira, C. W., Esteves, A. M., Bittencourt, L. R. A., Silva, R. S., Santos, R. F., … Mello, M. T. (2009). Sleep , ageing and night work. *Brazilian journal of medical and biological research*, *42*, 839–843.

Pisarski, A., Bohle, P., & Callan, V. J. (1998). Effects of coping strategies, social support and work-nonwork conflict on shift worker's health. *Scandinavian Journal of Work Environment & Health, Supplement*, 141–145.

Powell, N. B., Riley, R. W., Schechtman, K. B., Blumen, M. B., Dinges, D. F., & Guilleminault, C. (1999). A comparative model: reaction time performance in sleep-disordered breathing versus alcohol-impaired controls. *The Laryngoscope*, *109*(10), 1648–54. doi:10.1097/00005537-199910000-00019

Preacher, K., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments & Computers*, *36*(4), 717–731.

Presser, H. (2000). Nonstandard Work Schedules and Marital Instability. *Journal of Marriage and the Family*, *62*, 93–110.

Rankin, H., Serieys, N. M., & Elliott-Binns, C. (1987). Determinants of mood in general practitioners. *British Medical Journal*, *294*, 618–620.

Rau, R. (2006). The association between blood pressure and work stress: The importance of measuring isolated systolic hypertension. *Work & Stress*, *20*(1), 84–97. doi:10.1080/02678370600679447

Ream, E., & Richardson, a. (1996). Fatigue: a concept analysis. *International journal of nursing studies*, *33*(5), 519–29. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21455900

Ribet, C, & Derriennic, F. (1999). Age, Working Conditions, and Sleep Disorders: a Longitudinal Analysis in the French Cohort E.S.T.E.V. *Sleep*, *22*(4), 491–504.

Ribet, Céline, & Derriennic, F. (1999). Age , Working Conditions , and Sleep Disorders : a Longitudinal Analysis in the French Cohort E.S.T.E.V. *Sleep*, *22*(4), 491–504.

Richter, S., Marsalek, K., Glatz, C., & Gundel, A. (2005). Task-dependent differences in subjective fatigue scores. *Journal of sleep research*, (14), 393–400.

Robson, C. (2002). *Real World Research* (2nd ed.). Oxford: Blackwell Publishing.

Rogers, A., Spencer, M. B., & Stone, B. (1999). *Validation and development of a method for assessing the risks arising from mental fatigue*.

Rollinson, D. C., Rathlev, N. K., Moss, M., Killiany, R., Sassower, K. C., Auerbach, S., & Fish, S. S. (2003). The Effects of Consecutive Night Shifts on Neuropsychological Performance of Interns in the Emergency Department: A Pilot Study. *Annals of Emergency Medicine*, *41*(3), 400–406. doi:10.1067/mem.2003.77

Rosa, R. (1995). Extended workshifts and excessive fatigue. *Journal of sleep research1*, *4*(Supplement 2), 51–56.

Rosa, R., & Colligan, M. (1988). Long workdays versus restdays: Assessing fatigue and alertness with a portable performance battery. *Human Factors*, *30*(3), 305–317.

Rosekind, M. R., Gander, P. H., Connell, L. J., & Co, E. L. (2001). *Crew Factors in Flight Operations X : Alertness Management in Flight Operations Education Module*. *Aviation*. Moffet Field.

Rosekind, M. R., Smith, R., Miller, D. L., Co, E. L., Gregory, K. B., Webbon, L., … Lebacqz, V. (1995). Strategic naps.pdf. *European Sleep Research Society*, *4*, 62–66.

Rouch, I., Wild, P., Ansiau, D., Rouchy, I., Wildy, P., & Ansiauz, D. (2005). Shiftwork experience , age and cognitive performance Shiftwork experience , age and cognitive performance. *Ergonomics*, *48*(10), 1282–1293. doi:10.1080/00140130500241670

Rout, U. (1996). Stress among general practitioners and their spouses: a qualitative study. *British Journal of General Practitioners*, *46*, 157–160.

Rout, U., Cooper, C. L., & Rout, J. (1996). Job stress among british general practitioners: Predictors of job dissatisfaction and mental ill-health. *Stress Medicine*, *12*, 155–166.

Rupp, T. L., Wesensten, N. J., Bliese, P. D., & Balkin, T. J. (2009). Banking sleep: realization of benefits during subsequent sleep restriction and recovery. *Sleep*, *32*(3), 311–21. doi:10.1111/j.1365-2869.2009.00800.x

Ryan, B., Wilson, J. R., Sharples, S., Morrisroe, G., & Clarke, T. (2009). Developing a Rail Ergonomics Questionnaire (REQUEST). *Applied Ergonomics*, *40*, 219 – 229. doi:10.1016/j.apergo.2008.04.010

Saksvik, I. B., Bjorvatn, B., Hetland, H., Sandal, G. M., & Pallesen, S. (2011). Individual differences in tolerance to shift work e A systematic review. *Sleep Medicine Reviews*, *15*(4), 221–235. doi:10.1016/j.smrv.2010.07.002

Sallinen, M, Harma, M., Mutanen, P., Ranta, R., Virkkala, J., & Muller, K. (2003). Sleep-wake rhythm in an irregular shift system. *Journal of Sleep Research*, *12*, 103–112.

Sallinen, Mikael, Harma, M., Akila, R., Holm, A., Luukkonen, R., Mikola, H., … Virkkala, J. (2004). The effects of sleep debt and monotonous work on sleepiness and performance during a 12-h dayshift. *Journal of sleep research*, *13*, 285–294.

Sallinen, Mikael, & Kecklund, G. (2010). Shift work, sleep, and sleepiness - differences between shift schedules and systems. *Scandinavian Journal of Work, Environment & Health*, *36*(2), 121–133. doi:10.5271/sjweh.2900

Salminen, S. (2000). Traffic accidents during work and work commuting. *Industrial Ergonomics*, *26*, 75–85.

Samuels, B. C. H. (2001). Fatigue and Sleep : Making the Connection. *Sleep (Rochester)*, (October).

Saxena, A. D., & George, C. F. P. (2005). Sleep and motor performance in on-call internal medicine residents. *Sleep*, *28*(11), 1386–91. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16335328

Schernhammer, E. S., Laden, F., Speizer, F. E., Willett, W. C., Hunter, D. J., Kawachi, I., & Colditz, G. a. (2001). Rotating night shifts and risk of breast cancer in women participating in the nurses' health study. *Journal of the National Cancer Institute*, *93*(20), 1563–1568. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11604480

Schultz, H. (2008). Rethinking Sleep Analysis. *Journal of Clinical Sleep Medicine*, *4*(2), 99–103.

Shiffman, S. (2000). Real-time self-report of momentary states in the natural environment: Computerized ecological momentary assessment. In A. A. Stone, J. S. Turkkan, C. A. Bachrach, J. B. Jobe, H. S. Kurtzman, V. S. Cain, … V. S. E. Cain (Eds.), *The Science of SelfReport Implications for Research and Practice* (pp. 277–296). Lawrence Erlbaum Associates, Inc.

Signal, L. (2002). *Scheduled napping on the night shift: Consequences for the performance and neurophysiological alerness of air traffic controllers*. *Traffic*. University of Otago,.

Sloan, E. (2008). Sleep Disruption During Pregnancy. *Sleep Medicine Clinics*, *3*(1), 73–80.

Smith, I., & Shneerson, J. (1995). Is the SF 36 sensitive to sleep disruption? A study in subjects with sleep apnoea. *Journal of sleep research*, *4*(3), 183–188.

Smith, Lawrance, Tanigawa, T., Takahashi, M., Mutou, M., Tachibana, N., Kage, N., & Iso, H. (2005). Shiftwork, locus of control, situational and behavioural effects on sleepiness and fatigue in shiftworkers. *Industrial Health*, *43*, 151–170.

Smith, Lawrence, Folkard, S., Tucker, P. T., & Macdonald, I. (1998). Work shift duration : a review comparing eight hour and 12 hour shift systems. *Occupational and Environmental Medicine*, *55*, 217–229. doi:10.1136/oem.55.4.217

Smith, M. R., Cullnan, E. E., & Eastman, C. I. (2008). Shaping the light/dark pattern for circadian adaptation to night shift work. *Physiology & behavior*, *95*(3), 449–56. doi:10.1016/j.physbeh.2008.07.012

Smithers, F. (1995). The pattern and effect of on call work in transplant coordinators in the United Kingdom. *International journal of nursing studies*, *32*(5), 469–83. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8550307

Sonnentag, S., & Zijlstra, F. R. H. (2006). Job characteristics and off-job activities as predictors of need for recovery, well-being, and fatigue. *The Journal of applied psychology*, *91*(2), 330–50. doi:10.1037/0021-9010.91.2.330

Spencer, M. B., Robertson, K. A., & Folkard, S. (2006). *The development of a fatigue / risk index for shiftworkers*. *Technology*.

Spurgeon, A. (2003). *Working time Its impact on safety and health*. *Organization*.

Staal, M. A. (2004). *Stress , Cognition , and Human Performance : A Literature Review and Conceptual Framework*. *Processing*.

Stepanski, E. (2002). The effect of sleep fragmentation on daytime function. *Sleep*, *25*(3), 268–76. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12003157

Stepanski, E., Lamphere, J., Badia, P., Zorick, F., & Roth, T. (1984). Sleep fragmentation and daytime sleepiness. *Sleep*, *7*(1), 18–26. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/6718922

Stone, A., & Shiffman, S. (2002). Capturing momentary, self-report data: a proposal for reporting guidelines. *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine*, *24*(3), 236–43. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12173681

Straif, K., Baan, R., Goose, Y., Secretan, B., Ghissassi, E., Bouvard, F., … Cogliano, V. (2007). Carcinogenicity of shift-work, painting, and fire-fighting. *Lancet Oncol*, *12*(8), 1065–1066.

Strauss, A. L., & Corbin, J. M. (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. (P. Labella, Ed.)*Sage* (Vol. 2nd, p. 312). Sage Publications. Retrieved from http://www.amazon.ca/exec/obidos/redirect?tag=citeulike09-20&path=ASIN/0803959400

Sussman, D., & Coplen, M. (2000). Fatigue and alertness in the United States railroad industry part I : the nature of the problem. *Transportation Research Part F: Psychology and Behaviour*, *3*, 211–220.

Sutherland, V. J., & Cooper, C. (1996). *Stress prevention in the offshore oil and gas exploration and production industry*. *Stress: The International Journal on the Biology of Stress*. Geneva.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using Multivariate Statistics*. *Organization* (5th ed., Vol. 28, p. 980). Boston: Pearson. doi:10.1037/022267

Tassi, P., & Muzet, A. (2000). Sleep inertia. *Sleep Medicine Reviews*, *4*(4), 341–353. doi:10.1053/smrv.2000.0098

Tenenhaus, M., & Young, F. W. (1985). An analysis and synthesis of multiple correspondence analysis, optimal scaling, dual scaling, homogeneity analysis and other methods for quantifying categorical multivariate data, *50*(1), 91–119. doi:10.1007/BF02294151

Thorsteinsson, E. B., & Brown, R. F. (2009). Mediators and moderators of the stressor-fatigue relationship in nonclinical samples. *Journal of psychosomatic research*, *66*(1), 21–9. doi:10.1016/j.jpsychores.2008.06.010

Tobin, D., Holroyd, K., & Reynolds, R. (1984). *User's Manual for the Coping Strategies Inventory*. Ohio.

Torsvall, L., & Akerstedt, T. (1988). Disturbed sleep while being on-call: an EEG study of ships' engineers. *Sleep*, *11*(1), 35–38.

Totterdell, P., Spelten, E., Smith, L., Barton, J., & Folkard, S. (1995). Recovery from work shifts: how long does it take? *The Journal of applied psychology*, *80*(1), 43–57. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7706194

Trinkoff, A. M., Rong, L., Geiger-brown, J., Lipsvomb, J., & Lang, G. (2006). Longitudinal Relationship of Work Hours , Mandatory Overtime , and On-call to Musculoskeletal Problems in Nurses. *American Journal of Industrial Medicine*, *971*, 964–971. doi:10.1002/ajim.20330.

Tsutsumi, A., Kayaba, K., Kario, K., & Ishikawa, S. (2009). Prospective study on occupational stress and risk of stroke. *Archives of internal medicine*, *169*(1), 56–61. doi:10.1001/archinternmed.2008.503

Tucker, A. M., Whitney, P., Belenky, G., Hinson, J. M., & Van Dongen, H. P. a. (2010). Effects of sleep deprivation on dissociated components of executive functioning. *Sleep*, *33*(1), 47–57. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2802247&tool=pmcentrez&rendertype=abstract

Tucker, & Knowles, S. R. (2008). Review of studies that have used the Standard Shiftwork Index : Evidence for the underlying model of shiftwork and health. *Ap*, *39*, 550–564. doi:10.1016/j.apergo.2008.02.001

Turek, W. (1986). Circadian principles and design of rotating shift work schedules. *Journal of Physiology – Regulatory Integrative and Comparative Physiology*, *251*(3), 636–638.

Turner, C., & Stone, B. (2004). *Review of coping strategies to mitigate fatigue of train drivers*. *Human Factors*.

Van Amelsvoort, L. G. P. M., Jansen, N. W. H., & Kant, I. J. (2006). Smoking among shift workers: More than a confounding factor. *Chronobiology International*, *23*(6), 1105–1113.

Van der Hulst, M. (2003). Long work hours and health. *Scandinavian Journal of Work Environment & Health*, *29*(3), 171–188. doi:10.5271/sjweh.720

Van der Hulst, M., Meijman, T., & Rothengatter, T. (2001). Maintaining task set under fatigue : a study of time-on-task effects in simulated driving. *Transportation Research Part F 4*, *4*, 103–118.

Van Dongen, H. P. A. (2006). Shift work and inter-individual differences in sleep and sleepiness. *Chronobiology International*, *23*(6), 1139–1147.

Van Dongen, H. P. A., & Dinges, D. F. (2000). Circadian Rhythms in Fatigue, Alertness and Performance. (T. R. W. C. D. M H Kryger, Ed.)*Principles and practice of sleep medicine*, *3*(215), 391–399. Retrieved from http://www.nps.navy.mil/orfacpag/resumepages/projects/fatigue/dongen.pdf

Van Dongen, H. P. A., Maislin, G., Mullington, J. M., & Dinges, D. F. (2003). The Cumulative Cost of Additional Wakefulness : Dose-Response Effects on Neurobehavioral Functions and Sleep Physiology From Chronic Sleep Restriction and Total Sleep Deprivation. *Sleep*, *26*(2), 117–126.

Van Dongen, H. P. A., Rogers, H., & Dinges, D. (2003). Sleep debt: Theoretical and empiral issues. *Sleep and Biological Rhythms2*, *1*, 5–13.

Van Gelder, R., & Kao, J. (2006). Impact of being on-call. *Ophthalmology*, *113*(5), 889 – 890.

Waage, S., Moen, B. E., Pallesen, S., Eriksen, H. R., Ursin, H., Akerstedt, T., & Bjorvatn, B. (2009). Shift work disorder among oil rig workers in the North Sea. *Sleep*, *32*, 558–565.

Wertz, A. T., Ronda, J. M., Czeisler, C. A., Wright, K. P., & Owens, J. A. (2006). Effects of sleep inertia on cognition. *JAMA: The Journal Of The American Medical Association*, *295*(2), 163–164.

Wesnes, K. A., Walker, M. B., Walker, L. G., Heyst, S. D., White, L., Warren, R., & Oremint, O. (1997). Cognitive performance and mood after a weekend on call in a surgical. *British Journal of Surgery*, (84), 493–495.

Williams, C. (2008). Work-life balance of shift workers. *Prespectives*, (75), 5–16.

Williamson, A. (2007). Fatigue and coping with driver distraction. In I. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter, & J. Irwin (Eds.), *Distracted driving* (pp. 611–622). Sydney: Australasian College of Road Safety.

Williamson, A., Feyer, A., & Friswell, R. (1996). The impact of work practices on fatigue in long distance truck drivers. *Accident; analysis and prevention*, *28*(6), 709–19. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9006639

Wise, J. (2009). Danish night shift workers with breast cancer awarded compensation. *British Medical Journal*, *338*, b1152.

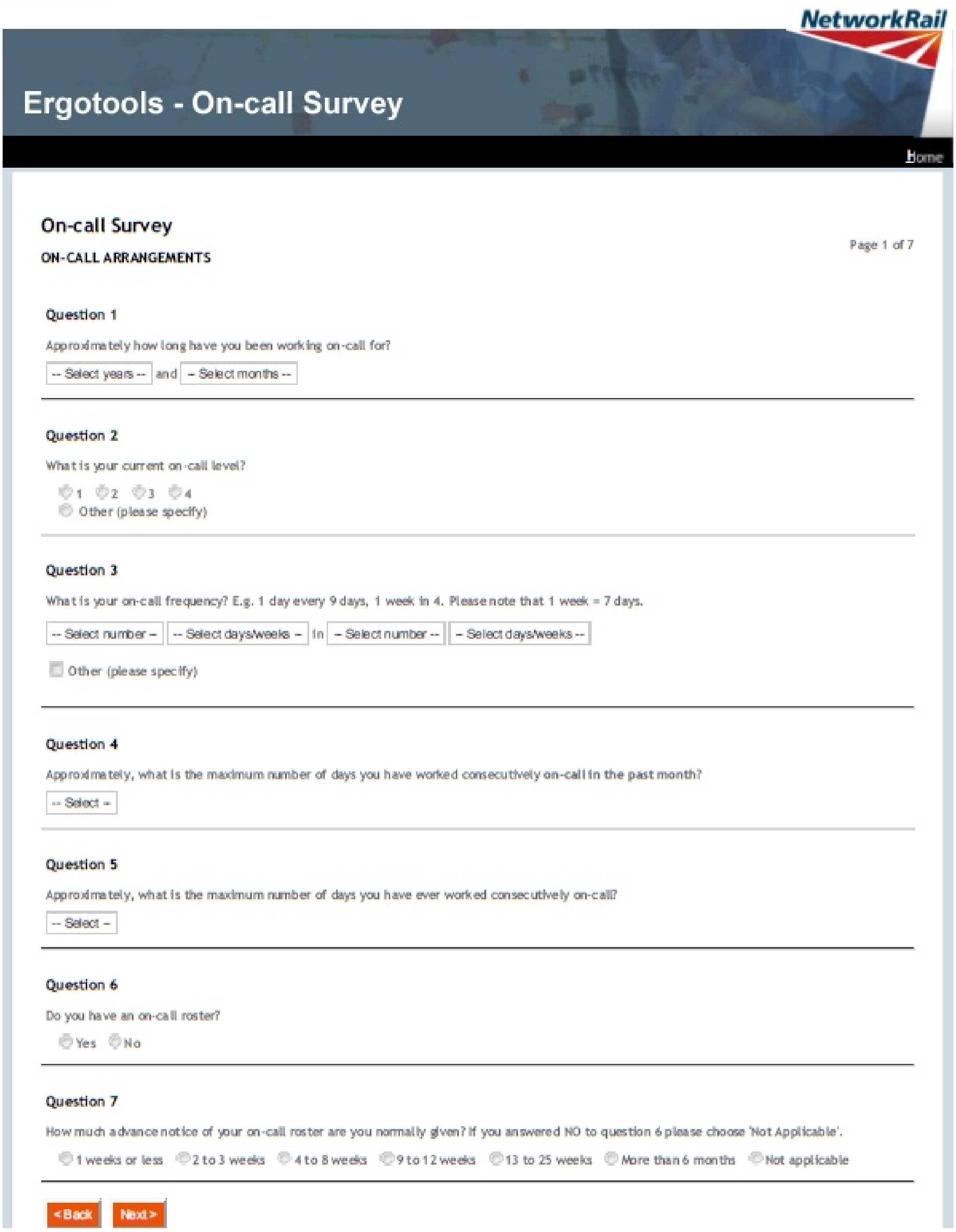
Woodward, J. A., Bonnett, D. G., & Brecht, M. L. (1990). *Introduction to linear models and experimental design*. (H. B. Javanovich, Ed.). San Diego.

Wu, A. W., Folkman, S., Mcphee, S. J., & Lo, B. (2003). Do house officers learn from their mistakes? *Quality and Safety in Healthcare*, *12*, 221–226. doi:10.1136/qhc.12.3.221

Xie, L., Kang, H., Xu, Q., Chen, M., Liao, Y., Thiyagarajan, M., … Nedergaard, M. (2013). Sleep Drives Metabolite Clearance from the Adult Brain. *Science*, *342*(6156), 373–377.

Appendixes

Appendix A - On-call questionnaire survey



NetworkRail

Ergotools - On-call Survey

Home

On-call Survey

Page 1 of 7

ON-CALL ARRANGEMENTS

Question 1

Approximately how long have you been working on-call for?

-- Select years -- and -- Select months --

Question 2

What is your current on-call level?

1 2 3 4

Other (please specify)

Question 3

What is your on-call frequency? E.g. 1 day every 9 days, 1 week in 4. Please note that 1 week = 7 days.

-- Select number -- -- Select days/weeks -- in -- Select number -- -- Select days/weeks --

Other (please specify)

Question 4

Approximately, what is the maximum number of days you have worked consecutively on-call in the past month?

-- Select --

Question 5

Approximately, what is the maximum number of days you have ever worked consecutively on-call?

-- Select --

Question 6

Do you have an on-call roster?

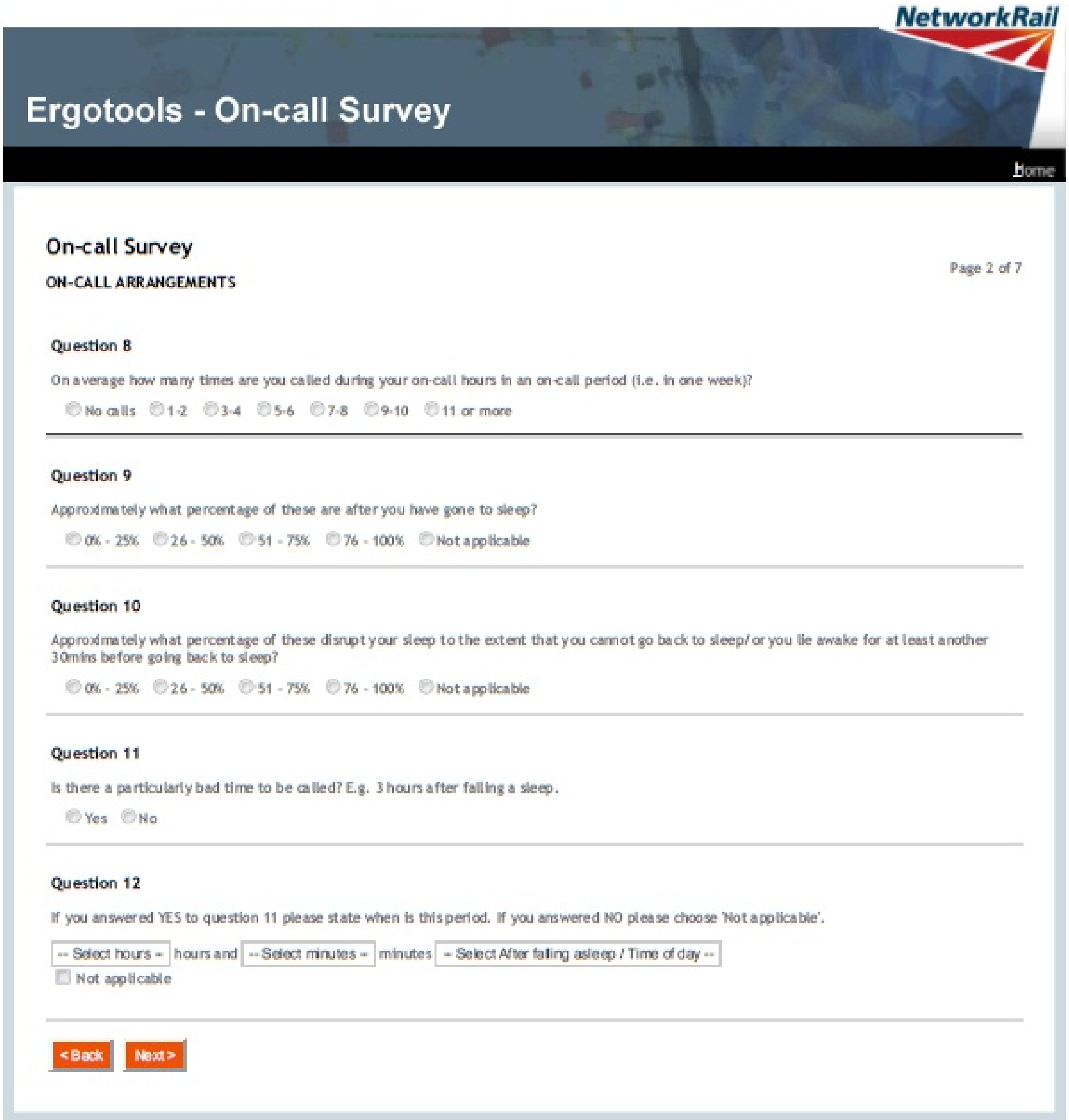
Yes No

Question 7

How much advance notice of your on-call roster are you normally given? If you answered NO to question 6 please choose 'Not Applicable'.

1 weeks or less 2 to 3 weeks 4 to 8 weeks 9 to 12 weeks 13 to 25 weeks More than 6 months Not applicable

< Back Next >



NetworkRail

Ergotools - On-call Survey

Home

On-call Survey

Page 2 of 7

ON-CALL ARRANGEMENTS

Question 8

On average how many times are you called during your on-call hours in an on-call period (i.e. in one week)?

○ No calls ○ 1-2 ○ 3-4 ○ 5-6 ○ 7-8 ○ 9-10 ○ 11 or more

Question 9

Approximately what percentage of these are after you have gone to sleep?

○ 0% - 25% ○ 26 - 50% ○ 51 - 75% ○ 76 - 100% ○ Not applicable

Question 10

Approximately what percentage of these disrupt your sleep to the extent that you cannot go back to sleep/ or you lie awake for at least another 30mins before going back to sleep?

○ 0% - 25% ○ 26 - 50% ○ 51 - 75% ○ 76 - 100% ○ Not applicable

Question 11

Is there a particularly bad time to be called? E.g. 3 hours after falling a sleep.

○ Yes ○ No

Question 12

If you answered YES to question 11 please state when is this period. If you answered NO please choose 'Not applicable'.

[-- Select hours --] hours and [-- Select minutes --] minutes [-- Select After falling asleep / Time of day --]

☐ Not applicable

< Back Next >

NetworkRail

Ergotools - On-call Survey

Home

On-call Survey

ABOUT WORK

Question 13

How many hours of sleep do you get on average per 'night' when?

On-call without receiving calls	-- Select --
On-call and receiving calls	-- Select --
Off-call	-- Select --

Question 14

How do you feel about the amount of sleep you normally get?

	1 - Nowhere near enough	2	3	4	5 - Get plenty
On-call without receiving calls	○	○	○	○	○
On-call and receiving calls	○	○	○	○	○
Off-call	○	○	○	○	○

Question 15

How well do you normally sleep?

	1 - Extremely badly	2	3	4	5 - Extremely well
On-call without receiving calls	○	○	○	○	○
On-call and receiving calls	○	○	○	○	○
Off-call	○	○	○	○	○

Question 16

How rested do you normally feel after sleep?

	1 - Definitely not rested	2	3	4	5 - Extremely rested
On-call without receiving calls	○	○	○	○	○
On-call and receiving calls	○	○	○	○	○
Off-call	○	○	○	○	○

Question 17

How tired (fatigued) do you usually feel

	1 - Not at all	2	3	4	5 - A lot
During your on-call period (week/day) without receiving calls?	○	○	○	○	○
During your on-call period (week/day) when you are called?	○	○	○	○	○
On a period (week / day) when you don't work on-call?	○	○	○	○	○

Question 18

What was the longest period of time you have worked on-call without sleeping? Please include any working hours (on-call or off-call) in your calculations. I.e. if you have worked a 8h shift till 4pm and then were working continuously on-call till midnight then your answer should be 13h to 16h.

○ 8h to 12h ○ 13h to 16h ○ 17h to 20h ○ 21h to 24h ○ More than 24h

< Back Next >

NetworkRail

Ergotools - On-call Survey

Home

On-call Survey

ABOUT WORK

Question 19

In general how much are the following affected when you are: On-call attending a fault on site

	1 - Not at all	2	3	4	5 - Very much so
Your decision making ability					
Your attention					
Your alertness					
Your speed of work					
Your quality of work					
Your mood					
Your motivation					

Question 20

In general how much are the following affected when you are: On-call performing a telephone consultation

	1 - Not at all	2	3	4	5 - Very much so
Your decision making ability					
Your attention					
Your alertness					
Your speed of work					
Your quality of work					
Your mood					
Your motivation					

Question 21

How stressed do you feel in general when:

	1 - Not at all	2	3	4	5 - Very much
On-call					
Not on-call					

Question 22

How anxious do you feel due to the following:

	1 - Not at all	2	3	4	5 - A very large extent
Expecting the phone to ring?					
Not knowing when and if you will get a call?					
The call itself?					
Other (please specify)					

NetworkRail

Ergotools - On-call Survey

Home

On-call Survey

Page 5 of 7

OVERALL VIEWS

Question 23

How satisfied are you with your:

	1 - Not satisfied at all	2	3	4	5 - Very satisfied
On-call arrangements					
Job in general					

Question 24

Are you satisfied with the amount of time your on-call work leaves you for:

	1 - Not satisfied at all	2	3	4	5 - Very satisfied	Not applicable
Hobbies and/or Sport activities						
Friends and family						
Yourself						

Question 25

How does your partner feel about you working on-call?

1 - Extremely unhappy 2 3 4 5 - Extremely happy Not applicable

Question 26

How would you rate the impact on-call work has on you in general?

1 - No impact 2 3 4 5 - Very Large impact

Question 27

How would you rate the general impact of working on-call on your:

	1 - No impact	2	3	4	5 - Very Large impact
Fatigue					
Stress					
General well-being					
Family life					
Social life					

Question 28

When NOT on-call how would you rate the general impact on your:

	1 - No impact	2	3	4	5 - Very Large impact
Fatigue					
Stress					
General well-being					
Family life					
Social life					

< Back Next >

NetworkRail

Ergotools - On-call Survey

Home

On-call Survey

Page 6 of 7

ON-CALL ARRANGEMENTS

Question 29

Is there the possibility that you are rostered to be on-call when on leave?

○ Yes ○ No

Question 30

Is there the possibility that you are rostered to be on-call on days off?

○ Yes ○ No

Question 31

If you answered yes to either of the previous 2 questions would you be (please select the options that apply):

☐ Required to work
☐ A replacement would be arranged
☐ My on-call would be swapped with a co-worker
☐ Other (please specify) ________

Question 32

Who is responsible for arranging cover if you happen to be on leave or on a day off when on-call?

○ Me ○ My manager ○ Not applicable
○ Other (please specify)

Question 33

For each of the following, please indicate how often you:

	1 - Almost never	2	3	4	5 - Almost always	Not applicable
Are required to change your on-call roster at short notice	○	○	○	○	○	○
Swap shifts with colleagues	○	○	○	○	○	○
Cover a colleague's shift	○	○	○	○	○	○

Question 34

Is it mandatory for you to work on-call or do you need to volunteer for it?

○ Mandatory ○ Voluntary

Question 35

When on-call are you required to maintain your normal working hours as well?

○ Yes ○ No

Question 36

To which extend are the following your main reasons for working on-call?

It is part of the job	○	○	○	○	○	○
I want to know what is happening	○	○	○	○	○	○
Higher rates of pay	○	○	○	○	○	○
To help out	○	○	○	○	○	○
Other (please specify)	________					

Question 37

Given the option would you prefer to do on-call?

○ 1- Definitely not ○ 2 ○ 3 ○ 4 ○ 5 - Definitely yes

< Back Next >

NetworkRail

Ergotools - On-call Survey

Home

On-call Survey

Page 7 of 7

GENERAL DEMOGRAPHIC INFORMATION

Question 38

Please indicate your age group

○ Under 25 ○ 25 to 34 ○ 35 to 44 ○ 45 to 56 ○ Over 56

Question 39

Please indicate your gender

○ Male ○ Female

Question 40

How long have you worked in the rail industry?

○ Less than 1 year ○ 1 to 5 years ○ 6 to 10 years ○ 11 to 19 years ○ 20 years or more

Question 41

How long have you been in your current position?

○ Less than 1 year ○ 1 to 5 years ○ 6 to 10 years ○ 11 to 19 years ○ 20 years or more

Question 42

Where is your main place of work?

-- Select --

Question 43

Approximately how many hours do you work each week including overtime?

(valid values: 0 to 100)

< Back   Next >

Appendix B - Questionnaire invite

Subject: On-call work survey – Tell us your views

Dear Colleague

As part of the ongoing industry wide review of fatigue management arrangements, we are directly seeking your views regarding your current **on-call** systems of work, which we believe cannot be robustly gathered via the current feedback channels in place.

This is your chance to share your views and directly affect how on-call work will be managed in the near future.

We have prepared a brief online survey that will take **10 to 15 minutes** to complete. All replies are **anonymous** and will be treated **confidentially**.

Please cascade to all Section Managers and Supervisors that undertake 'on call' arrangements for Network Rail Maintenance.

To complete the survey please click HERE.

If this link does not work, please copy and paste the following link into internet explorer: http://oncallsurvey.ergotools.co.uk/

Thank you in advance; your feedback is very valuable to us.

Please Note: The National Ergonomics team is responsible for undertaking this survey. Please contact Nuno Cebola if you have any questions or comments at: nuno.cebola@networkrail.co.uk / 08578366

Regards,

Justin Page

Head of Infrastructure Maintenance Safety and Compliance

Network Rail

M: 07515 627762

E: justin.page@networkrail.co.uk

Appendix C – Diary protocol

At the beginning of on-call shift		
Anxiety	Fatigue	Mood
0	0	0

For each callout record:						
	Time	Ended	Asleep	Out	Ability	BTS
1	00:00	00:00	00:00	Y/N	Y/N	00:00/NA
2						
3						
4						
5						
6						
7						
8						
9						
10						

In the morning:			
In bed at	Asleep	Got Up at	Sleep quality
00:00	00:00	00:00	0

Anxiety	Fatigue	Mood
0	0	0

NOTE	1 = Low / Good	5 = High / Bad

On-call Diary questionnaire

1 Please indicate your age group:

2 Please indicate your gender:

3 How long have you been working in the rail industry?

4 How long have you been in your current position?

5 Approximately how many hours do you work each week including overtime?

6 Approximately how long have you been working on-call for?

Select years	Select months

7 What is your on-call frequency? E.g. 1 week in 4 weeks

Select number	Select days/weeks		Select number	Select days/weeks
		in		

1. Introduction

As part of the ongoing industry wide review of fatigue management arrangements we are collecting data regarding the on-call system of work via this diary study. The aim of this diary is to collect specific data regarding the timing and amount of callouts and how you perceive these to affect your sleep, fatigue, and performance both during the night and the following days.

2. When should I take part

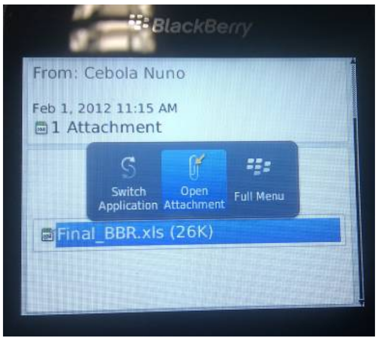
We would like you to take part for a period twice as long as your on-call period starting on the first day of your on-call period e.g. if your on-call period is 1 week then you should record your data for **2 weeks**. For the duration of this period you will be asked to keep a log of all callouts and record how you feel in your diary. When not on-call please continue recording all work related calls you receive outside your normal working hours and how you feel.

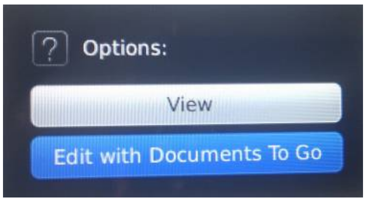
3. What do I do now?

Due to the anonymous set up of the questionnaire you filled in before we are unable to match your on-call arrangements so before starting with the diary you will be required to re-fill that information in a short questionnaire. All data for this study will be collected using Microsoft Excel on your **Blackberry phone** and your **Network Rail email account**. If you have not done so yet please email Nuno Cebola at nuno.cebola@networkrail.co.uk informing him of when your next on-call period is starting and for how long and you will be sent a new spreadsheet every day during the duration of the study.

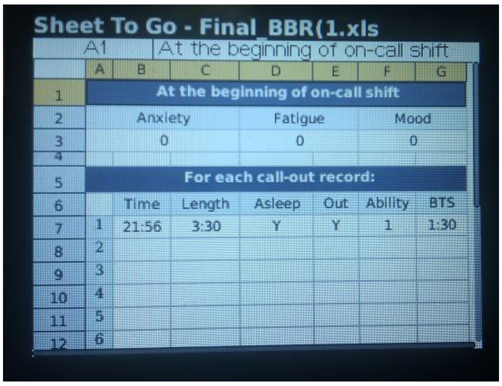
4. What do I do each day?

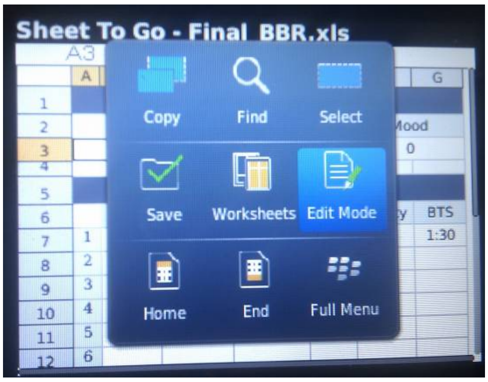
Each day, at the beginning of your on-call shift, open your daily spreadsheet using the "*Edit with documents to go*" mode in your Blackberry - see figures below (opening the document in *view mode* means you won't be able to edit it and the formatting will look wrong).





After opening the document the diary sheet will appear in your blackberry screen as shown below. To input your information you will firstly have to select *edit mode* once more and then fill in each field.





At the end of each on-call shift send your spreadsheet back to Nuno Cebola at nuno.cebola@networkrail.co.uk If you have any comments please add them to the email otherwise simply send the spreadsheet.

5. How do I fill in the diary?

Your diary is divided into 3 sections that will now be described in detail.

1. *At the beginning of on-call shift / At the end of your shift*
2. *For each callout*
3. *In the morning*

At the beginning of on-call shift / At the end of your shift

The first section should be filled in at the beginning of your on-call shift for each specific on-call day. For the period of time you are not working on-call but still taking part in this study you should fill this section at the end of your day shift.

These questions are concerned with how you feel at the beginning of your on-call shift and should be answered using values between 1 and 5 in accordance to the rating scales shown below.

Question	Scale				
How anxious do you feel?	1 – Not anxious at all	2	3	4	5 – Very anxious
How fatigued do you feel?	1 – Not fatigues at all	2	3	4	5 – Very fatigued
How is your mood?	1 – Very good mood	2	3	4	5 – Very bad mood

Example:

At the beginning of on-call shift		
Anxiety	Fatigue	Mood
1	2	4

- In this example the on-call member of staff is not anxious at all.
- He is slightly fatigued and in a bad mood.

For each callout

This section is concerned with each of the callouts you receive during your on-call period no matter how short. If you are required to make several phone calls to deal with one callout you should **only record the one original callout**. All other calls will be treated as "working period" which will figure in the *ended* category. If you receive more than 10 callouts record your callouts up to the 10th and when sending your spreadsheet to the researcher also inform him of this. For each callout input your information as detailed in the table below.

Name	Question	Scale				
Time	The time you received the callout.	Time in **HH:MM**				
Ended	The time the callout terminated?	Time in **HH:MM**				
Asleep	Were you asleep when you received the callout?	Yes or No – **Y/N**				
Out	Were required to attend the fault?	Yes or No – **Y/N**				
Ability	How able did you feel to perform your duties?	1 – Very able	2	3	4	5 – Not able at all

BTS	When did you go BACK TO SLEEP?	Time in **HH:MM**

Example:

For each call-out record:						
	Time	Ended	Asleep	Out	Ability	BTS
1	00:45	01:15	Y	N	5	01:45
2						
3						
4						
5						
6						
7						
8						
9						
10						

- In this example the on-call member of staff received a callout at 00:45 which ended at 01:15.
- He was already a sleep at the time and was not required to attend the fault.
- He didn't feel able at all to deal with the calls – this can be due to fatigue, stress, or even the nature of the call itself – the reasons behind this are not requested.
- Finally after finishing the callout he could only go back to sleep at around 01h45min in the morning.

In the morning

This section should be completed the morning after the on-call period and relates to the quantity and quality of your sleep together with how you feel.

For the sleep quantity and quality section please introduce the information requested as shown in the following table.

	Question	**Scale**				
In bed at	The time you went to bed	Time in **HH:MM**				
Asleep	The estimated time you fell a sleep	Time in **HH:MM**				
Got up at	The time you got up in the morning	Time in **HH:MM**				
Sleep quality	How well did you sleep?	1 – Very well	2	3	4	5 – Very poorly

The second part is concerned with how you feel before the beginning of your normal shift. These scales are identical to the ones used in *"At the beginning of your on-call shift/ At the end of your shift"* and should be answered using the same values between 1 and 5 as described in the table below.

Question	Scale				
How anxious do you feel?	1 – Not anxious at all	2	3	4	5 – Very anxious
How fatigued do you feel?	1 – Not fatigues at all	2	3	4	5 – Very fatigued
How is your mood?	1 – Very good mood	2	3	4	5 – Very bad mood

Example

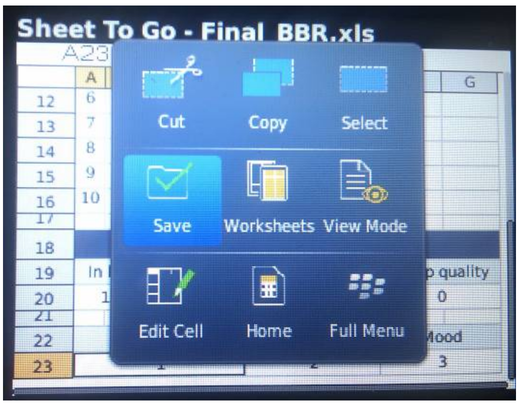
In the morning:			
In bed at	Asleep	Got Up at	Sleep quality
22:30	23:00	06:00	2

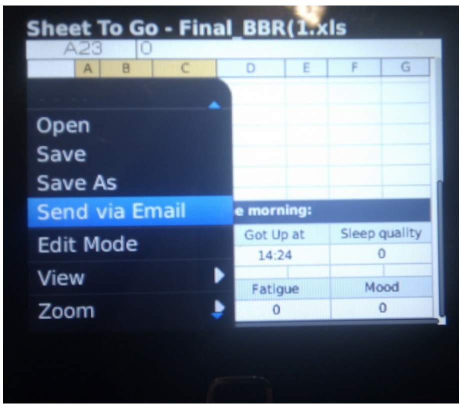
Anxiety	Fatigue	Mood
1	1	1

- In this example the on-call worker went to bed at 22h30mins and estimates it took him around 30minutes to fall asleep.
- He got up at 06:00h and his sleep quality was good.
- He is not anxious or fatigued and his mood is very good.

6. Completion

After completing each of the sections save the document and after completing the last section in the morning send it to Nuno Cebola at nuno.cebola@networkrail.co.uk





If you do not understand any part of these instructions or are uncertain about any part of them please get in touch with the researcher directly at nuno.cebola@networkrail.co.uk

Appendix D – Interview invite

On-call survey participation invitation

The ergonomics team is investigating the management of the **on-call scheduling system of work** and we would like to give you a chance to talk about how this type of work is scheduled, managed, and how it affects you. The aim of this work is to first and foremost identify scheduling practices and management processes of the on-call working system and how these affect those involved in this system of work.

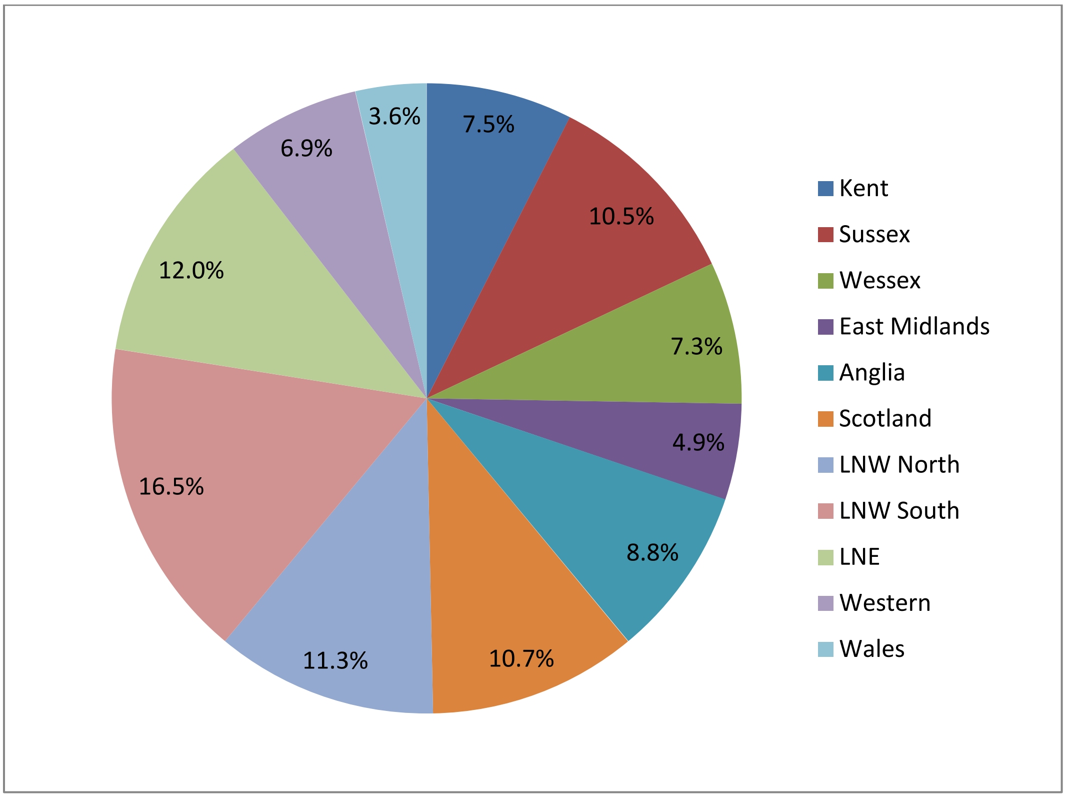
The research will involve an interview where you will be asked to expand on your ideas on the on-call scheduling system of work. The interviews are to be recorded on tape with your permission and each is expected to last between 45min and 1h. Tape recording is simply for note taking and the topics to be addressed during the interview will be supplied prior to the interview for your consideration.

All of the information you give us will be treated securely and in the strictest confidence. **Any information that is recorded by us will be made anonymous** if they are to be used in any reports etc. No personal information of any kind will be passed to any third parties unconnected with the study. Prior to the beginning of the interview you will also be asked to sign a consent form stating you agree with these conditions and the treatment of the information you give us. The consent form will also be signed by the interviewer. You will be free to leave the study at any time.

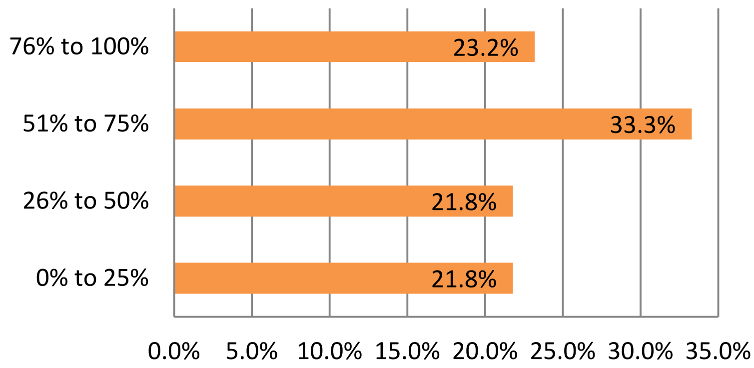
Participation in this research is **voluntary** and is your opportunity to share your ideas and your concerns regarding this system of work and to affect how it will be managed in the future. **We are interested in learning how this type of work affects you and those around you.**

If you would be interested in participating please let your team organizer know of your interest.

Appendix E – Responses per Route

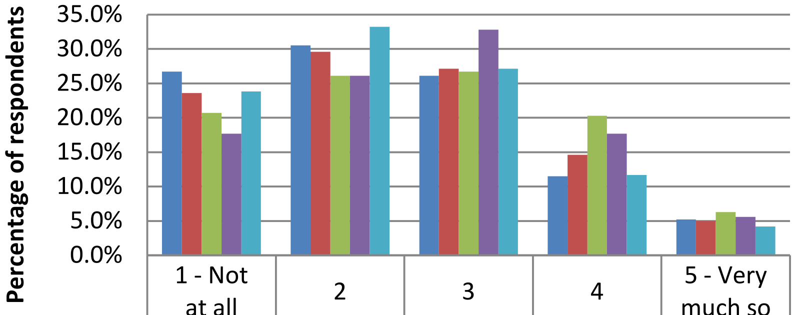


Appendix F – Percentage of callouts when already asleep



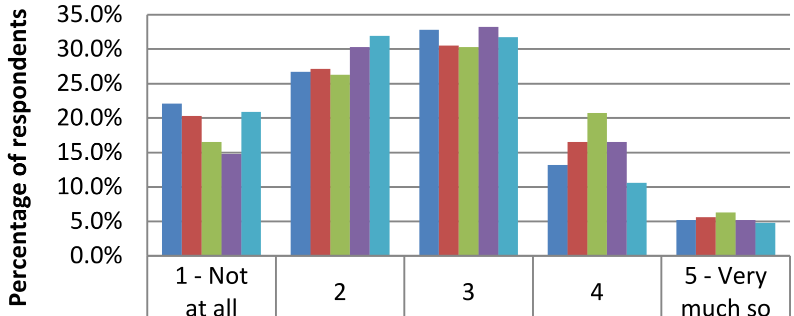
	0% to 25%	26% to 50%	51% to 75%	76% to 100%
Percentage of call-outs when already asleep	21.8%	21.8%	33.3%	23.2%

Appendix G – Graphic distribution of performance factors affected when on the telephone



	1 - Not at all	2	3	4	5 - Very much so
Decision making	26.7%	30.5%	26.1%	11.5%	5.2%
Attention	23.6%	29.6%	27.1%	14.6%	5.0%
Alertness	20.7%	26.1%	26.7%	20.3%	6.3%
Speed of work	17.7%	26.1%	32.8%	17.7%	5.6%
Quality of work	23.8%	33.2%	27.1%	11.7%	4.2%

Appendix H – Graphic distribution of performance factors affected when attending site



	1 - Not at all	2	3	4	5 - Very much so
Decision making	22.1%	26.7%	32.8%	13.2%	5.2%
Attention	20.3%	27.1%	30.5%	16.5%	5.6%
Alertness	16.5%	26.3%	30.3%	20.7%	6.3%
Speed of work	14.8%	30.3%	33.2%	16.5%	5.2%
Quality of work	20.9%	31.9%	31.7%	10.6%	4.8%

Appendix I – On-call guidelines

On-call scheduling: research based guidance

Prepared By:
Nuno Cebola, Date 10/04/13

Reviewed By:
Emma Lowe, Date __________

Network Rail Ergonomics Team

On-call work

A recent European wide research has shown that on-call work is quickly becoming the most common system of work across Europe (Eurofound, 2012). On-call work is now more common that shift work and night work.

As a company NR greatly relies on on-call work as it is a cheaper alternative to other types of work like shift work as on-call work does not require 24/7 coverage. In effect, a large number of both frontline and managerial staff are currently required to operate under this working hours scheduling system. However, very little is known about the management procedures across the company and much variance seem to exist across DUs.

The project

Over the last three years a joint research project between the Ergonomics team and the University of Nottingham has investigated the idiosyncrasies of on-call work at NR's Infrastructure Maintenance. This project was separated into three studies. Study 1 was an exploratory study where 72 interviews were conducted at five DUs both with frontline and managerial level on-call staff. The results identified that a large quantity of call-outs received are thought to be unnecessary. For example, calls passing on irrelevant information, calls that are not deemed urgent and could have waited until the morning, and mainly, the need to constantly send or receive updates to several stake holders that get involved in the incident. Other issues that were identified were the lack of rostering details which recurrently lead to situations where on-call staff have been called when not actually working on-call and staff being rostered to work on-call when on annual leave or on a scheduled day off. Several concerns regarding fatigue, well-being, and performance were also identified specially on managerial roles. This is mainly due to the daily demands of the work that managers are required to attend regardless of the events of the night.

Based on these findings a questionnaire was compiled to assess their generality. This was Study 2 with its results supporting the findings of Study 1. Of the 479 respondents, 91% stated on-call arrangements do not match up with their working hours arrangements and, as such, there is the possibility for them to be rostered to work on-call whilst on rostered days off or when having a rostered weekend off.

The final study was a two week diary study where voluntary staff recorded numbers of calls and their perceived impact during an on-call week and the following not on-call week. Results revealed a large individual variation on the numbers of call-outs received indicating the existence of a chronologic, geographic, or role related influence (or combinations of all). Length and timings of calls were also found to vary greatly with the majority of calls taking no more than 5 minutes but some requiring several hours of work. The results also shown that even short calls can cause several hours of disruption as it can take up to an hour for staff to fall back asleep.

Guidance

This project is now reaching its final stages and on-call work management guidelines and recommendations have been produced. The following guidance and recommendations are proposed:

- Define a clear list of appropriate events that require on-call staff to be disturbed. These should be role dependent and should be compiled accordingly,
- Define a clear list of stakeholders that must be involved and/or informed regarding specific incidents,
    - A Responsible, Accountable, Contributing, Informed (RACI) document could be produced to make this simple and clear to all involved in the process.
- Move on-call responsibility for as many of these events as possible to 24/7 roles, i.e. Fault Control
- Limit calls after 23h and no calls between 00:00 and 04:00. This can be achieved by:
    - Identifying levels of urgency for each event. Only high emergency calls should be routed to on-call staff,
    - Creating call windows – where instead of being on-call for the whole night on-call staff is given a specific time window when to receive call-outs (e.g. until all possessions are taken),
    - Move night shift staff management responsibilities to a 24/7 role when possible,
    - After being called-out provide staff with 12h rest breaks to meet the legal requirements of the European Working time Directive 2003/88/EC, and NR's Management of Working Hours standard NR/ERG/003.
- Regularise and manage on-call rosters centrally:
    - On-call staff should not be booked to work on-call during days off or when on annual leave. This prevents actual breaks from work.
    - Mistakes are known to occur when on-call staff have been called-out when not actually working on-call.
- Implement an on-call monitoring system to:
    1. Monitor numbers and timings of call-outs,
    2. Assess call-out trends,
    3. Allow for live modifications to on-call rosters to better manage trend peaks and staff fatigue.

References

Eurofound. (2012). 5th European Working Conditions Survey. Luxembourg.

On-call scheduling: Research based management principles

Prepared By:
Nuno Cebola, Date 05/07/13

Reviewed By:
Emma Lowe, Date __________

Network Rail Ergonomics Team

On-call work

A recent European wide research has shown that on-call work is quickly becoming the most common system of work across Europe (Eurofound, 2012). On-call work is now more common that shift work and night work across Europe.

As a company NR greatly relies on on-call work as it is a cheaper alternative to other types of work like shift work as on-call work does not require 24/7 coverage. In effect, a large number of both frontline and managerial staff are currently required to operate under this working hours scheduling system. However, very little is known about the management procedures across the company and much variance seem to exist across DUs.

The project

Over the last three years a joint research project between the Ergonomics team and the University of Nottingham has investigated the idiosyncrasies of on-call work at NR's Infrastructure Maintenance. This work is now reaching its conclusion and the full report and data sets will be available in late 2013.

This project was separated into three studies. Study 1 was an exploratory study where 72 interviews were conducted at five DUs both with frontline and managerial level on-call staff. The results identified that a large quantity of call-outs received are thought to be unnecessary. For example, calls passing on irrelevant information, calls that are not deemed urgent and could have waited until the morning, and mainly, the need to constantly send or receive updates to several stake holders that get involved in the incident. Other issues that were identified were the lack of rostering details which recurrently lead to situations where on-call staff have been called when not actually working on-call and staff being rostered to work on-call when on annual leave or on a scheduled day off. Several concerns regarding fatigue, well-being, and performance were also identified especially on managerial roles. This is mainly due to the daily demands of the work that managers are required to attend regardless of the events of the night.

Based on these findings a questionnaire was compiled to assess the generality of these factors for managerial staff. This was Study 2 and the results mainly supported the findings of Study 1. Of the 479 respondents, 91% stated on-call arrangements do not match up with their working hours arrangements and, as such, there is the possibility for them to be rostered to work on-call whilst on rostered days off or when having a rostered weekend off. A large impact on both stress and fatigue was also identified and the majority of on-call staff stated that given the chance they would prefer not to work on-call. Numbers, length, and timing of calls were identified as key factors which impact on sleep and as such on fatigue. Further support was also found regarding the need to maintain day oriented tasks and activities (meetings and day to day management of work).

The final study was a two week diary study where voluntary staff recorded numbers of calls and their perceived impact during an on-call week and the following not on-call week. Results revealed a large individual variation on the numbers of call-outs received indicating the existence of a chronologic, geographic, or role related influence (or combinations of all these). Length and timings of calls were also found to vary greatly. The majority of calls took no more than 5 minutes but some requiring several hours of work. The results also shown that even short calls can cause several hours of disruption as it can take up to an hour for staff to fall back asleep. This was found to be mainly due to ruminating on the content of calls.

Based on this research the following on-call management principles are proposed together with suggestion on specific actions that can help achieve them:

- ***Minimise numbers of calls***
    - A list of appropriate events that require on-call work per role should be produced, periodically reviewed, and made available to all parties concerned,
    - Identifying levels of urgency for each event and an appropriate time to respond. Low emergency events could potentially be dealt with on the following day,
    - A Responsible, Accountable, Contributing, Informed (RACI) document could be produced to make this simple and clear to all involved in the process,
    - Where possible move on-call responsibility for as many of these events to available 24/7 roles.
- ***After a call, minimise disruption and length of on-call work***
    - Define a clear list of stakeholders that must be involved and/or informed regarding specific incidents,
    - Arrange a phone conference to provide updates to all stakeholders and interested parties – these would minimizes the number of calls to workers dealing with the issue.
- ***Implement an on-call monitoring system***
    - Monitor numbers and timings of calls,
    - Assess call trends,
    - Allow for live modifications to on-call rosters to better manage trend peaks and staff fatigue.
- ***Limit number of calls per on-call shift***
    - Consider modifying on-call rosters to allow more resilience to multiple calls – are traditional on-call rosters (x weeks in y weeks) the most effective and fatigue friendly method to work on-call?
    - Consider using ways to reduce the number of calls received by on-call members of staff – for example: using calling windows or primary and secondary on-call staff.
- ***Regularise and manage on-call rosters centrally***
    - Central repository of on-call rosters to prevent on-call staff being booked to work on-call during days off or when on annual leave which inhibits actual breaks from work,
    - Controlled on-call documents to be sent out to Fault Control - uncontrolled documents are know to lead to mistakes causing on-call staff to be called when not actually working on-call,

- Limit number of on-call shifts one can do and when – this will help prevent excessive covering which can results in one member of staff working several weeks on-call.

A more prescriptive set of research based guidelines was also produced and is available on CCMS2 with the document number: 63894607

References

Eurofound. (2012). 5th European Working Conditions Survey. Luxembourg.