Ross Owen Phillips
Fridulv Sagberg
TØI report 1081/2010

Institute of Transport Economics
Norwegian Centre for Transport Research

Managing driver fatigue in occupational settings

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Summary:

This report reviews fatigue management programmes in occupational settings – a promising and burgeoning approach to driver fatigue. Although the causes of fatigue transcend the driver's home and work life, occupational programmes can contain elements that both minimize fatigue risk due to work-time activity and help the employee manage fatigue outside work. Common components of programmes to date, which mostly target the occupational driver, are schedule management, education, and sleep disorder screening and treatment. To date few programmes monitor fitness-for-duty, use employee incentives, promote an open reporting culture, or use competency-based selection and recruitment as part of the ongoing fatigue management attempt. While many programmes and official guidelines are research-based, more robust and independent evaluations are needed to assess their effect on fatigue-related incidents and accidents. This is important because fatigue management as part of normal HSE activity of organisations has the potential to reduce fatigue-related accidents involving professional and private drivers alike.

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Sammendrag:

Denne rapporten undersøker en lovende måte å takle trøtthet bak rattet på, nemlig å benytte arbeidsbaserte programmer som tar sikte på å forebygge trøtthet blant ansatte. Programmene kan inneholde elementer som både minsker risikoen for arbeidsrelatert trøtthet og hjelper den enkelte ansatte til å mestre trøtthet utenfor arbeidet. De fleste programmer som har vært brukt hittil, har yrkessjåfører som mål. Vanlige programelementer er forbedret planlegging av tids- og skiftplaner, utdanning om trøtthet bak rattet, samt oppdagelse og behandling av søvnforstyrrelser blant ansatte. Derimot er det få programmer som måler førerens dagsform, bruker insentiver, fremmer åpen rapporteringskultur, eller bruker rekruttering med atferdsforankrete ferdigheter som grunnlag. Selv om de fleste programmer og retningslinjer baseres på forskning, er det behov for flere robuste og uavhengige evalueringer for å kunne si noe om deres effekt på trøtthetsulykker. Dette er viktig fordi trøtthetsmestring som ett fokus for HMS- aktivitet i organisasjoner potensielt kan redusere forekomsten av trøtthetsulykker, for yrkessjåfører så vel som for private.

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Preface

This report is one outcome of the programme of activities carried out by the ERA-NET TRANSPORT Action Group ENT15: Sleepiness at the wheel. The aim of the programme is to describe the problem of fatigue in driving and evaluate the effectiveness of certain countermeasures.

One promising countermeasure is to tackle fatigue in driving by implementing fatigue management programmes in occupational settings. Such programmes are increasingly being implemented by organizations employing professional drivers. They also have the potential to effectively target employees as private drivers, though little has been done in this area to date. A timely review of fatigue management programmes – to catalogue common elements, knowledge gaps, and evaluate their effectiveness – was therefore included as part of the Group's activities.

We wish to thank our ENT15 partners at TNO, VTI, the Karolinska Institute and CNRS for their comments at the outset of the project. In particular we would like to thank TNO for collaboration on the YAWN project, which is included as part of the ENT15 programme.

At TØI, Fridulv Sagberg has been project manager. Ross Owen Phillips has researched and written the report. Rune Elvik has been responsible for quality assurance. Trude Rømming has edited and prepared the report for printing.

Oslo, August 2010
Insitute of Transport Economics (TØI)

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Summary:

Managing driver fatigue in occupational settings

A promising way to tackle driver fatigue is to implement programmes in occupational settings. Although the causes of fatigue transcend the driver's home and work life, we find that organisational programmes can contain elements that both minimize fatigue risk due to work-time activity and help the employee manage fatigue at home. Common components of programmes to date, primarily aimed at the occupational driver, are schedule management, education, and sleep disorder screening and treatment. There are few programmes that monitor fitness-for-duty, use employee incentives, promote an open reporting culture, or use competency-based selection and recruitment, as part of the ongoing fatigue management attempt. While many programmes and official guidelines are research-based, more robust and independent evaluations are needed to assess their effect on fatigue-related incidents and accidents. This is important because fatigue management as part of normal HSE activity of all types of companies has the potential to reduce fatigue-related accidents involving professional and private drivers alike.

Fatigue is a major cause of road accidents. It has the potential to affect any driver, but is an increasing problem for professional drivers who must drive further than ever before to enable their employers to compete in an increasingly global 24/7 economy.

Through delivery at organisational level, Fatigue Management Programmes (FMPs) could be more effective than mass media campaigns for tackling the problem of fatigue in professional and private drivers alike. The company is more able to target its employees using tailor-made measures, and it can more effectively monitor and manage fatigue outcomes. Systematic assessment of FMPs carried out to date is lacking, but is needed to evaluate their efficacy and, if appropriate, encourage the wider uptake and implementation of FMPs by relevant road transport companies.

This report is a review of company-based programmes for fatigue management based on a literature search. It aims to:

- Assess the extent to which FMPs are based on current research
- Describe and catalogue various component measures of FMPs
- Assess qualitatively the accident reduction potential of FMPs
- Document knowledge gaps and research needs as a basis for subsequent studies aimed at quantifying the effectiveness of FMPs

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Current research on fatigue in occupational driving – influences, outcomes and management

A substantial proportion of professional drivers routinely experience fatigue in a way that influences their performance. The consequences of this are implicit in the high prevalence of bus and truck driver accidents – especially serious ones – in which fatigue is the main cause. To tackle the problem there has been substantial research to identify factors associated with fatigue in private and occupational driving. This finds that a routine, extended, non-interrupted sleep obtained at night is the most effective way fatigue can be limited, implying an important role for the individual driver in fatigue management. Other research suggests that good sleep hygiene and a healthy lifestyle should be promoted among drivers, who should also be screened and treated for health conditions associated with fatigue. Fatigue risks associated with physiological and psychosocial influences during and outside work hours should be carefully considered, as should those risks particular to younger and older drivers.

The most important organizational level influence on fatigue appears to be the driver's schedule, not least because it determines whether the opportunity for sleep is:

- long enough for sufficient recuperative sleep in the context of demands placed on the driver;
- given at a time of day that is appropriate for recuperative sleep; and
- routine and predictable.

A driver's schedule also prescribes the time of day at which the driving is performed, a factor which is strongly linked to self-reported driver fatigue and fatigue-related incidents in operational environments. More general research suggests that by designing jobs organizations also prescribe the extent to which drivers can manage their own fatigue, and the knowledge, information and feedback they are given to do so. The prevailing safety culture of the organization is strongly implied in the level of fatigue risk that will be perceived by the driver as acceptable, and in particular what a driver perceives that other drivers do about fatigue. Research also suggests that fatigue risks will be increased if fatigue-related behaviourally anchored competencies are not used as the basis for driver selection and recruitment. Finally, the monotony of the road on which the driver drives may have particular importance for fatigue development in long-haul trucking.

Various outcomes of fatigue can be measured to guide its management. These include (i) direct reports of fatigue as experienced by drivers; and (ii) the effects of fatigue implicit in cognitive or driving performance, aspects of driver physiology, and various organisational outcomes e.g. near miss incidents and accidents, costs due to lost productivity, absenteeism, turnover, reduced morale, increased wear and tear on equipment, and health and wellbeing.

The company can intervene at four levels to control those factors associated with fatigue and manage associated fatigue outcomes. It can:

(i) limit the consequences of fatigue on driving performance;
(ii) prevent a fatigued driver from falling asleep when driving;
(iii) prevent fatigue developing during driving; or
(iv) prevent a driver entering a vehicle while fatigued.

Our analysis implies that the organisation should focus on targeting measures at levels (iii) and (iv). Specific measures should be selected by the individual company based on the findings of a needs analysis in which subjective fatigue, driver sleep, behavioural indicators of fatigue and/or driving performance are recorded over a period to inform the subsequent intervention.

Management of fatigue can be assisted by tools and technologies in the following areas:

- Programme implementation – fatigue policy development, needs analysis tools, competency development.
- Driver, manager or other stakeholder education – training modules to increase knowledge and awareness of fatigue, outline coping strategies, or explain how diet and health is connected to fatigue.
- Schedule development and analysis – software packages available based on biomathematical models can help account for sleep history, circadian influences and in some cases sleep intertia; the models predict future fatigue risks.
- Fitness-for-duty measurement – using relatively well-established psychovigilance tasks, which can be performed in the cabin on palm-top computers, and bench-top instruments for pupil analysis.
- Driver performance assistance – eye-closure monitors to warn a driver that he is fatigued; and devices that can help drivers with the physical effort of driving in high winds.

Research shows that the following considerations should be made when using these tools:

- Modular training packages should be adapted to suit the particular organisation in which they are used. Any training should be designed based on a needs analysis for that organisation, outlining the competencies that need to be trained. The effects of training packages on actual behaviour, performance or operational measures are not clear, and directed group discussions may be a more inexpensive alternative.
- Scheduling tools are useful ways to implement evidence-based knowledge on fatigue in ways that managers can understand, and in some cases practicality and functionality has been demonstrated. There are some problems to address. These include manager over-reliance on fatigue risk predictions; that they do not account for considerable inter- and intra-individual variations in fatigue proneness; and that they only consider a few of the many influences on fatigue.
- More field studies are needed to assess the validity of fitness-for-duty indicators.
- Although still in development, technology that can measure and assist driver performance is becoming an increasingly realistic option, especially for large long-haul companies.

Surprisingly, no tool is available that helps managers select FMP elements according to the particular contingencies of the organisation.

Managing fatigue at organizational level – pros and cons

The report details how sectoral developments and increasing recognition about limitations of hours of work regulation has led to the growth of organizational-level management of fatigue and FMPs. Other lines of evidence also support that organisational-level management of fatigue would be beneficial.

However, there are some drawbacks of FMPs. They are expensive to implement, and small companies are likely to be daunted by the staff consultation, policy drafting, technology purchase, documentation, auditing and change in organisational culture that FMP implementation may demand. A challenge for regulatory authorities is therefore how they can encourage companies to take on more responsibility for fatigue management. Recent evidence suggests that this is being achieved increasingly by attempting to persuade companies that they need to manage fatigue like any other risk, within an effective safety management system.

FMP evaluation

A robust evaluation is required to learn whether an FMP has been successful and/or inform its further development. Operational limitations will prevent ideal experimental design, but organisations should at least aim to evaluate a time series of measures recorded over two periods, each lasting at least several months, one before and one after the intervention. Ideally, the change between periods should be compared with a corresponding change at similar sites or that coinciding in organisations where there is no intervention.

Many independent evaluations of FMP interventions need to be carried out and reported to inform regulatory authorities, safety associations, politicians and transport organisations about their effects. Alongside the change in outcomes reported, evaluations should report on the culture and context of the organisation involved. Only then will we be able to begin generalising about the effects an FMP is likely to have for a given organisation.

Analysis of an inventory of FMPs / FMP guidelines

To qualitatively assess FMPs carried out to date, a total of 61 documented FMPs were retrieved and reviewed. The programmes range from a single measure implemented by a single company to comprehensive guidelines issued by a regulatory authority. The FMPs come from North America, Australasia and Europe. Thirty-two are described for the road sector, 14 for aviation, six for rail and seven for the maritime sector. Just under half are pilot or demonstration projects carried out by regulatory bodies, safety associations, research institutes or universities, while a similar number are descriptions or evaluations of manuals, “toolboxes” of elements, codes of practice, standards or guidelines for FMPs issued mostly by regulatory authorities.

The most commonly implemented FMP components are:

- schedule management
- education
- sleep disorder management

In other words the FMPs reported employ elements described in the research literature as serving to tackle the causes of fatigue. Encouragingly, this suggests that current FMPs are evidence-based.

Furthermore several FMPs incorporate additional elements, which research suggests promotes the management of fatigue by the driver. These include feedback on sleep or fatigue levels, with personal or training advice on coping strategies that might be effective. Sleep contracts are also used in some FMPs, and there is some research basis for this.

Guidelines on FMPs have been issued by authorities or institutes. Although they are nearly always evidence-based, the effect of implementing the guidelines is not normally evaluated. The guidelines emphasise the three core elements above. Commitment to fatigue policy and a need to address the work environment are also emphasized, and these elements are not uncommon in FMPs actually implemented by organisations.

Several guidelines recommend measures that do not often appear in reports by organisations actually implementing FMPs. These include the following:

- fitness-for-duty monitoring
- promotion of an open reporting (‘just’) culture
- competency-based selection and recruitment
- procedures to ensure the fatigue of temporary or contract personnel is addressed
- employee incentives
- evaluation and refinement of the programme against stated aims

For FMP implementation, resistance to change is a recognised issue. Transport companies have attempted to tackle this using nominated fatigue management coaches or champions; visibly effective demonstration projects; involvement of all stakeholders from the outset; multi-level, multi-disciplinary project teams; and end-user participation in FMP design.

Most FMP evaluations are not controlled. The time the evaluation measures were taken in relation to the programme roll-out is often not clear. Many of the available evaluations are not independent. Most outcome measures reported are training outcomes or reports of subjective fatigue. Evaluations of organisational context coinciding with FMP implementation are wholly lacking.

Recommendations

The following research needs are highlighted:

- A better understanding and explicit demonstration of the causative relationship between fatigue and safety outcomes.
- Knowledge of the normal variability in fatigue levels within and between individual drivers.
- Mapping of fatigue effects as they diffuse through organisational systems.
- A better understanding of the drivers and limiters of FMP uptake.
- An industry survey to chart safety culture in EU road transport companies and link this to the way they manage fatigue.
- A better understanding of the organizational contingencies for different FMP elements.
- A better understanding of how different influences on fatigue interact.

- Demonstration evaluations of guideline implementation.
- Development and publication of a simple-to-use evaluation tool to standardize and promote robust evaluations to help reach valid conclusions about FMP effects.
- A study of the effectiveness of incentives and sleep contracts as FMP elements.

Recommendations for road transport companies designing and implementing FMPs include the following:

- Underpin the FMP with a clear fatigue policy.
- Policy should explicitly set out how managers and drivers should deal with the paradox between need for punctual delivery by driver and driver need for rest (conflict between fatigue management and logistics)
- Organizational conditions important to FMP acceptance and effectiveness should be explicitly considered and changed if necessary e.g. management trust, openness of reporting culture, driver autonomy.
- Set out procedures to explicitly address the fatigue of temporary or contract personnel
- As part of implementation there should be up-front consultation with key stakeholders, and procedures to manage resistance to change
- Behaviourally anchored competencies should be described and used as a basis for recruitment and selection in line with fatigue policy
- Address how to increase the visibility of driver fatigue as an issue to all stakeholders
- Select FMP measures to prevent employees entering a vehicle while fatigued; and prevent fatigue developing during driving
- Consider in addition to core FMP elements (schedule management; education; health monitoring and treatment) the exploitation of valid, usable, accepted, reliable, cost-effective technologies to assess fitness for duty as they become available
- Ensure through training that those using scheduling software do not over-interpret group-based predictions of fatigue risk
- Evaluate the intervention independently, using a battery of implicit and explicit measures of fatigue, and use to evolve the FMP towards stated aims

While a competitive organisation may have little reason to openly report the results of FMP evaluation, we recommend that regulatory bodies encourage open reporting by transport companies through promotion and funding of independent evaluations.

Finally, recommend that the incorporation of FMPs as part of normal HSE management in *all types* of companies (i.e. not just road transport companies) be considered as a way to improve the limited impact of road safety campaigns on employee fatigue during private driving.

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Sammendrag:

Organisatoriske programmer for mestring av førertrøtthet

En lovende måte å takle trøtthet bak rattet på er å benytte organisatoriske programmer som tar sikte på å forebygge trøtthet blant ansatte. Arbeidsbaserte programmer kan inneholde elementer som både minsker risikoen for arbeidsrelatert trøtthet og hjelper den enkelte ansatte til å mestre trøtthet utenfor arbeidet. De fleste programmer utført hittil har yrkessjåfører som mål. Vanlige programelementer er forbedret planlegging av tids- og skiftplaner, utdanning om trøtthet bak rattet, samt oppdagelse og behandling av søvnforstyrrelser blant ansatte. Derimot er det få programmer som måler førerens dagsform, bruker insentiver, forfremmer åpen rapporteringskultur, eller bruker rekruttering med atferdsforankrete ferdigheter som grunnlag. Selv om de fleste programmer og retningslinjer baseres på forskning, er det behov for flere robuste og uavhengige evalueringer for å kunne si noe om deres effekt på trøtthetsulykker.

En hovedgrunn til at ulykker på veg oppstår, er trøtthet bak rattet. Hvem som helst som kjører kan rammes, men særlig yrkessjåfører står overfor et stort problem. Dette er ikke minst på grunn av at de kan oppleve tidspress for å sette sine arbeidsgivere eller oppdragsgivere i stand til å konkurrere i markedet.

Programmer som forebygger trøtthet blant ansatte har stort potensial for å begrense trøtthet blant både profesjonelle og private førere. Bedrifter kan tilpasse metoder og redskap til sine ansatte, og kan også måle og styre trøtthetsmål effektivt. Imidlertid mangler det en systematisk vurdering av aktuelle programmer for å evaluere effektivitet og eventuelt oppmuntre bedrifter til å implementere slike programmer videre.

Denne rapporten gir en oversikt over organisatoriske programmer for å håndtere trøtthet blant førere. Den tar sikte på

- å undersøke i hvilken grad programmene har forskning som grunnlag;
- å beskrive elementer brukt i programmene;
- å evaluere kvalitativt hvorvidt programmene reduserer ulykkestall;
- å dokumentere hvilke opplysninger som vil muliggjøre en kvantitativ evaluering av programmene.

Trøtthet blant yrkessjåfører – påvirkninger, mål og styring

Både private førere og yrkessjåfører er ofte rammet av trøtthet på en måte som går ut over deres prestasjon. Faktisk skyldes en høy andel av buss- og lastebilulykker førertrøtthet. Det har dermed vært mye forskning for å identifisere faktorene knyttet til trøtthet både i privat og profesjonell kjøring. Forskningen finner at regelmessig, lang og uforstyrret søvn om natta er den mest effektive måten å begrense trøtthet på, noe som tyder på at den enkelte fører har en viktig rolle å spille for å mestre sin egen trøtthet bak rattet. Forskningen tyder på at gode søvnvaner og en sunn livsstil bør fremmes blant førere for å forebygge problemer tilknyttet trøtthet. Det bør også være screening og behandling av eventuelle søvnforstyrrelser eller andre aktuelle sykdommer. Psykososiale og fysiologiske innflytelser på trøtthet burde også tas hensyn til, sammen med problemer som yngre og eldre førere er særlig utsatt for.

Gjennom å sette opp tidsplaner, skiftplaner og kjøreruter bestemmer organisasjonen om søvnmuligheter er:

- lange nok for tilstrekkelig søvn gitt alle kravene stilt til føreren;
- gitt på en tid på døgnet når føreren kan sove godt;
- regelmessige og forutsigbare.

Arbeidsplaner bestemmer også på hvilken tid på døgnet kjøringen gjøres, noe som har nær sammenheng med både selvrapportert førertrøtthet og trøtthetshendelser. Forskning viser at organisasjonen har betydning for hvor mye førere kan styre sin egen trøtthet, og hvor mye opplysning og tilbakemelding de får for å få hjelp til dette. Sikkerhetskulturen som dominerer vil også påvirke trøtthetsnivået den enkelte føreren anser som akseptabelt.

Det finnes flere indikatorer og konsekvenser som kan brukes som mål for å styre trøtthet. Disse inkluderer (i) selvrapportert trøtthet av førerne; og (ii) endringer i kognitiv prestasjon, kjøreprestasjon eller fysiologi; eller (iii) ulike organisatoriske konsekvenser, som for eksempel farlige hendelser, ulykker, kostnader knyttet til produktivitet, velvære og sykefravær.

Bedriften kan gripe inn på fire trinn for å styre faktorer knyttet til trøtthet og dermed konsekvensene av trøtthet. Den kan:

(i) Begrense konsekvensene av trøtthet for førerens prestasjon.
(ii) Forebygge at den trøtte føreren sovner bak rattet.
(iii) Forebygge trøtthet fra å utvikle seg i løpet av kjøreturen.
(iv) Forebygge den trøtte føreren fra å begynne på en kjøretur.

Analyser tyder på at det er best om bedriften fokuser mest på trinn (iii) og (iv). Mål bør velges avhengig av den enkelte bedriften. Målene kan baseres på funnene fra en behovsanalyse der subjektiv trøtthet, søvn, atferdsindikatorer og/eller kjøreprestasjon er registrert over en periode som grunnlag for etterfølgende intervensjon.

Styring av trøtthet kan gjennomføres ved bruk av redskap og teknologier på følgende områder:

- Programmer for å utvikle strategi for å håndtere trøtthet, gjennomføre behovsanalyser og utvikle kompetanse.

- Utdanning av førere, ledelse eller andre interessenter – opplæringsmoduler for å spisse kunnskap om trøtthet, skissere strategier for å greie trøtthet, forklare hvordan diett og helse henger sammen med trøtthet.
- Utvikling av tids- og skiftplaner – blant annet ved hjelp av programvare basert på biomatematiske modeller med utgangspunkt i forskning om søvn og døgnrytme.
- *Fitness-for-duty* måling – ved bruk av forholdsvis veletablerte perseptuelle og kognitive tester, som kan gjennomføres på bærbar pc-er; og redskap for pupillanalyse.
- Hjelpemidler for kjøreprestasjon – utstyr som overvåker øynene for å advare føreren når han blir trøtt; og hjelpemidler for å redusere den fysiske belastning, for eksempel ved lastebilkjøring.

Imidlertid er de foreliggende verktøy i liten grad tilpasset til å hjelpe ledere til å bestemme hvilke programelementer som passer best for den enkelte bedrift.

Evaluering av programmer for mestring av trøtthet

Det er behov for robust evaluering for å kunne fastslå hvorvidt et program har lykkes og å gi grunnlag for videreutvikling. Selv om driftsbetraktninger begrenser valg av evalueringsmetode, bør bedriften evaluere flere mål over to perioder, én før og én etter at programmet starter. Ideelt sett skal forandringen mellom de to periodene sammenlignes med en tilsvarende forandring på et lignende sted der programmet ikke settes i gang.

Flere uavhengige evalueringer av programmer for trøtthetshåndtering bør utføres og rapporteres for å gi kunnskap til myndigheter og sikkerhetsorganisasjoner, politikere og samferdselsorganisasjoner. Sammen med endringene i trøtthetsmål bør evalueringer også oppgi detaljer om bedriftens kultur og kontekst. Dette trenges for å kunne overføre erfaringer om effektene av slike programmer på tvers av ulike organisasjoner.

Analyse av en katalog over organisatoriske programmer for mestring av førertrøtthet

For å kunne vurdere kvalitativt de programmene som er utført hittil, ble 61 dokumenterte programmer undersøkt. Det finnes betraktelig variasjon blant programmene. Et program kan for eksempel være et enkelt mål gjennomført av et enkelt selskap eller det kan være sammensatte retningslinjer utgitt av reguleringsmyndigheter. Programmene kommer fra Nord Amerika, Australasia og Europa. Trettito er beskrevet fra vei, 14 fra luftfart, seks for jernbane og sju fra sjøfartssektoren. Litt under halvparten er piloter eller demonstrasjonsprosjekter utført av reguleringsmyndigheter, sikkerhetsorganisasjoner eller forsknings-institusjoner, og en lignende andel er standarder, retningslinjer, manualer eller *toolboxes* utgitt av transportmyndigheter.

Komponenter som oftest brukes er:

- Styring av tids- og skiftplaner
- Opplæring
- Håndtering av søvnforstyrrelse

Med andre ord benytter programmene elementer som er hensiktsmessige ifølge forskningslitteraturen.

Programmene inneholder iblant ytterligere elementer basert på forskning, nemlig tilbakemelding om trøtthet og søvn, og personlig råd eller opplæring for å informere om effektive mestringsstrategier. Såkalte søvnkontrakter er med i noen få programmer, og det finnes forskningsgrunnlag også for det.

Retningslinjer for organisatoriske programmer for mestring av trøtthet er utgitt av myndigheter eller institutter. Selv om disse ofte baseres på forskning, er deres effekt nesten aldri evaluert. Retningslinjene understreker de tre kjerneelementene nevnt ovenfor. De legger også vekt på kunngjøring av og synlig engasjement i organisasjonens trøtthetsstrategi, sammen med et behov for å håndtere arbeidsmiljøet. Slike elementer er egentlig ikke uvanlig i programmene som utføres i praksis.

Imidlertid opptrer følgende mål sjelden i programrapporter utgitt av organisasjoner, selv om de er anbefalt i flere retningslinjer:

- *Fitness-for-duty* overvåking
- Stimulering av åpen rapporteringskultur
- Rekruttering basert på kompetanse
- Prosedyrer for å håndtere trøtthet blant midlertidige ansatte
- Insentiver
- Evaluering og målrettet forbedring av programmet.

Motstand mot endring er erkjent som en viktig utfordring ved gjennomføring av et program. Transportbedrifter har forsøkt å håndtere dette ved bruk av ansatte som fungerer seg som coacher eller talsmenn for trøtthetsmestring; synlige demonstrasjonsprosjekter; engasjement av alle interessentene i utgangspunktet; og førernes deltakelse i utforming av programmet.

De fleste programevalueringer benytter ikke kontrollgruppe. Akkurat når evalueringsmålene er tatt i forhold til programmets begynnelse er ofte ikke klargjort. Mange evalueringer er ikke uavhengige. De fleste mål som er brukt er opplæringseffekter (f eks kunnskap, holdninger) eller selvrapportert trøtthet, dvs ikke ulykkestall eller kjøreprestasjon. Det er dermed vanskelig å si noe om hvorvidt programmene reduserer trøtthetsulykker. Det mangler også undersøkelser av den organisatoriske konteksten rundt de programmene som er gjennomført.

Anbefalinger

Forskningsbehov er identifisert som følger:

- Økt forståelse og eksplisitt påvisning av forholdet mellom trøtthet, kjøreprestasjon og trøtthetshendelser og -ulykker.
- Kunnskap om hvor mye trøtthet varierer mellom og innenfor individer.
- Kartlegging av hvordan trøtthetseffekter sprer seg gjennom organisatoriske systemer.
- Undersøke vegtransportbedrifter i EU for å kartlegge sikkerhetskultur og hvordan den henger sammen med måten de håndterer trøtthet på.
- Forståelse av det som øker og reduserer sannsynligheten for at organisasjoner vil implementere programmer for trøtthetsmestring.
- Evaluere effekt av retningslinjer i praksis.
- Utvikle og publisere verktøy for evaluering av programmer

Anbefalinger for vegtransportbedrifter er som følger:

- Støtte programmet med en tydelig og synlig strategi.
- Strategien skal beskrive hvordan punktlighet kan balanseres med førerens behov for å hvile.
- Organisatoriske betingelser som baner veien for positiv mottakelse av programmet skal klargjøres.
- Et viktig ledd i programmets gjennomføring er konsultasjon med alle interessenter fra begynnelsen.
- Atferdsforankrete kompetanser skal beskrives og brukes som grunnlag for rekruttering i tråd med trøtthetsstrategien.
- Vurdere hvordan synligheten av førertrøtthet kan økes for alle interessenter.
- Velge ut programmål som forhindrer ansatte fra å sette seg inn i et kjøretøy i trøtt tilstand; og forebygge utvikling av trøtthet i løpet av kjøreturen.
- I tillegg til det vi identifiserer som kjerneelementer (informert styring av tids- og driftplan; opplæring; screening og behandling av helse) skal andre nyttige tiltak vurderes, særlig verktøy for å overvåke dagsform.

Abbreviations and operationalisation of terms

No report on fatigue management would be complete without saying what is meant by the term fatigue. We employ the following definition:

Fatigue is the inability to function at the desired level due to incomplete recovery from demands of prior work and other waking activities. Acute fatigue can occur when there is inadequate time to rest and recover from a work period. Cumulative or chronic fatigue occurs when there is insufficient recovery from acute fatigue over time. Recovery of fatigue (…) requires (sufficient rest and) sleep (Gander, Hartley et al. 2010)

We use the term fatigue management programme (FMP) broadly. To us it describes *a concerted effort to manage fatigue in a transport setting using at least one organised intervention*. This definition also encompasses fatigue risk management systems (FRMS). An FRMS often exists within a pre-existing safety management systems (SMS) framework, where an SMS is an *explicit, comprehensive and systematic approach to managing risk.*

In order to avoid confusion, the term operator is used in the main text to denote an individual in control of a road vehicle, aircraft, boat or train. We do not use it to denote a transport company or transport organisation, although this *is* done in the FMP inventory given in the Appendix in order to remain faithful to the original FMP descriptions.

We do not define a distance to distinguish between long and local/short haul drivers. Fatigue is recognised as a problem for both drivers, even though the precise causes of fatigue may differ (Hanowski, Wierwille et al. 2003).

1 Background and aims

Fatigue causes sleepiness and is detrimental to attention, recall, reaction time, hand-eye coordination and vigilance (Gall 2006; Caldwell, Mallis et al. 2009). The implications for the driver are serious.

It is well established that drivers who are fatigued are more likely to have a serious accident than drivers who are not fatigued (Liu, Wu et al. 2005; Williamson, Lombardi et al. 2010). Reports based on comprehensive accident analyses place fatigue alongside alcohol as one of the major causes of road accidents (Horne and Reyner 1995; Philip, Vervialle et al. 2001). In many senses, however, fatigue is a bigger problem than alcohol. It is less well understood, it can neither be seen nor measured directly, and the onset of its effects is more difficult to predict. Evidence suggests that drivers are not inclined to postpone a journey as a result of feeling fatigued, and if they feel fatigued while driving they often carry on driving (Reyner and Horne 1998; Nordbakke and Sagberg 2007). Drivers are insufficiently aware of the risks associated with fatigued driving, and are not inclined to view driving while tired as socially unacceptable (Jettinghoff, Staren et al. 2005).

The problem of fatigue applies for professional and private drivers of all types of vehicles (Jettinghoff, Staren et al. 2005). As global business and social trends lead us to drive longer and further at all times of the day or night, the problem will only become worse unless it is tackled. In order to do this we need to understand more about fatigue, how it can be countered and by whom.

In 2008 the ERA-NET TRANSPORT programme began funding a series of studies to further chart the problem of fatigue and evaluate the effects of certain countermeasures. These studies were grouped under the umbrella of Action Group ENT15: Sleepiness at the Wheel.

ENT15 involved research teams from France (CNRS), Norway (TØI), The Netherlands (TNO) and Sweden (Karolinska Institute and VTI). The studies included a case-control crash investigation study; an evaluation of the effectiveness of traditional and blue light countermeasures; an investigation into driver awareness of fatigue; a national survey on the role of rumble strips in fatigued driving; and a review and evaluation of fatigue management in occupational settings. The latter is the subject of this report.

1.1 Fatigue management in occupational settings

Campaigns against sleepy driving directed at the general driving population seem to have a limited effect. An alternative arena for influencing drivers is the occupational setting, and there have been several attempts to establish various programmes for fatigue management in companies. At face value, such efforts could be expected to be more effective than campaigns directed to the general public, partly because the company may combine different measures, like work organisation, information to employers and employees, as well as incentive and reward systems. However, there seems to be a lack of scientific assessments of these programmes.

1.2 Aims

The purpose of this report is a review of company-based programmes for fatigue management based on a literature search. Its specific aims are as follows:

1) To assess qualitatively the accident reduction potential of such programmes and actions;
2) To describe various component measures that have been incorporated;
3) To document knowledge gaps and research needs as a basis for subsequent studies aimed at quantifying the effectiveness of such programmes and actions.

To help achieve these aims we accessed material from recent conferences on fatigue management, and searched literature databases for reports and evaluations of fatigue management interventions.

We were aware from the outset that most fatigue management programmes aimed at tackling driver fatigue had been carried out by companies employing occupational drivers. The focus of this report thus falls naturally on this group of drivers. However, by learning about the measures used and approaches taken by companies wishing to reduce fatigue in their professional drivers, we also hoped to reach valid conclusions and recommendations for potential company-level interventions directed at employees as private drivers.

1.3 How the report is structured

To provide a basis for assessing current company-based fatigue management programmes, we begin in Chapter 2 by reviewing factors commonly associated with fatigue and fatigue-related accidents in occupational driving. In Chapter 3 we examine what the current research says about how these factors can be managed effectively. In Chapter 4 we describe some of the tools and technologies available to companies wishing to manage fatigue, while in Chapter 5 we describe how fatigue management in occupational settings has grown out of a need for more effective management of fatigue in contemporary organisations. In Chapter 6 we consider the best ways to evaluate the effectiveness of FMPs from a theoretical point of view.

Together Chapters 2 to 6 form the basis for the qualitative evaluation of an inventory of attempts to manage fatigue in occupational settings, which we go on to describe in Chapter 7. We wanted our consideration of the management of fatigue in road transport settings to be informed by fatigue management approaches in other transport sectors. To this end Chapter 7 considers efforts to manage fatigue mainly in the road sector, but also in the rail, aviation and maritime sectors.

We summarise our findings in Chapter 8, and in Chapter 9 draw conclusions and recommendations for future work.

2 Fatigue in occupational driving – prevalence, causes and outcomes

Fatigue is one of the main reasons why the occupational risk for truck drivers is higher than average (Williamson, Feyer et al. 2000; Elvik, Høye et al. 2009). To survive in a global 24/7 economy, transport companies are under increasing pressure to keep trucks continuously on the road, asking their drivers to work more overtime and drive further than ever before (Gertler, Popkin et al. 2002). Set against a pattern of increased demands and less sleep in the general population, fatigue in occupational driving has emerged as a serious and developing problem (Dawson, Noy et al. 2010).

Traditionally, measures other than sleep have been used by drivers to counter fatigue, that at best are only briefly effective (Tasca 2006; Nordbakke and Sagberg 2007). A particularly prevalent strategy among truck drivers has been to fight off fatigue by sheer will, but this is now known to be wholly unsuccessful when severe fatigue sets in (Moore-Ede 1996).

Over the past 20 years, research has been carried out to scope the prevalence of fatigue in driving and the conditions in which it occurs, so that it can be better understood.

2.1 Prevalence

Several studies have attempted to chart the incidence of fatigue in truck drivers and the prevalence of fatigue-related accidents in which they are involved (Hartley 2007).

The incidence of fatigue is high. In an Australian project half of the truck drivers surveyed reported experiencing fatigue on their last trip (Feyer and Williamson 2000). A recent naturalistic observation of long and short haul truck drivers in the US found that as much as 3.5 per cent of driving time was spent in a drowsy state, during which road attention and monitoring behaviours were significantly reduced (Barr, Yang et al. 2005).

Fatigue has been reported as the one factor most associated with truck driver accidents (Boivin 2000). A row of detailed studies of bus and truck driver accidents in the 1980s found that drivers were asleep at the wheel in at least ten per cent of collisions, with fatigue as a major contributor in 25 per cent of collisions (Brown 1994). The American Automobile Association examined 221 crashes where the truck had to be towed away after the accident, ascribing fatigue as a primary cause in 40 per cent of crashes (Hartley 2007). A more recent comprehensive analysis of nearly one thousand large truck crashes estimated that 13 per cent of drivers were severely fatigued at the time of the crash (Craft 2009).

But fatigue-related crashes are not only common; they are also more serious in nature. An extensive literature review carried out in 1988 concluded that fatigue was a factor in five to ten per cent of all crashes, 20 to 30 per cent of casualty crashes and 25 to 35 per cent of fatal crashes [cited in (Smiley 1998)].

There is also an elevated risk to occupational drivers from 'carry-over' fatigue (Brown 1994). As they drive home after several shifts, the risks of a fatigue-related accident may be highest (Maycock 1996). Although relatively little work has been done here, the odds of fatigue occurring and the odds of an accident are both known to increase substantially on driving home after a long shift (Barger, Cade et al. 2005; Gander, Hartley et al. 2010).

In light of the prevalence and risks of fatigue in occupational driving, efforts are being made to develop effective ways to manage it. Recommendations are often informed by empirical studies delineating the causes of and influences on fatigue. Many of these studies are laboratory- or simulator-based, although field studies have been encouraged and are increasingly common.

The findings of these studies are reviewed below in order to provide a basis on which to judge whether current fatigue management programmes account for current knowledge. Although the causes of fatigue have been reviewed several times before, this has not been done from the perspective of an organisation wishing to manage fatigue in order to improve the performance and wellbeing of its employees.

The following review classifies fatigue influences according to whether they are more associated with the individual or the organisation. Factors considered at individual level are actual sleep; individual differences; and family and friends. Those considered at organisational level are timing, regularity and length of sleep opportunity; job design; job culture; work environment; employee health and wellbeing; and job competencies.

2.2 Individual level influences on fatigue

2.2.1 Actual sleep

A person who has slept poorly or insufficiently, either on one occasion or cumulatively over several or many occasions, is said to have built up a sleep debt. The result of a sleep debt is sleepiness, a reluctance to exert effort, and ultimately a reduction in task performance. Along with time of day, sleep debt is usually the most important factor influencing an individual's sleepiness. The nature of the sleep debt at any point in time is determined by several factors, most notably i) quality of sleep; ii) time since previous sleep; iii) length of previous sleep; iv) cumulative sleep deficit; and v) recovery from cumulated sleep deficit.

2.2.1.1 Quality of sleep

The most important factor relating to sleep quality are sleep disorders or other aspects of health that affect how deeply and consistently one can sleep.[1]

[1] Further dealt with under Individual Differences below

There is surprisingly little work assessing how the sleeping environment impacts on the quality of sleep, although a 1996 US study in which 80 drivers were observed across 4000 hours of driving, found some evidence of cumulative fatigue after several days of driving and sleeping in bunks (cited in (Moore 1998)).

Sleep taken during the daytime is often poor in quality.[2]

2.2.1.2 Time since previous sleep
Studies of fatigue accidents involving truck drivers generally show that the number of hours a driver has been awake is not as important as the number of hours driven or on duty since he has last slept (Gander, Waite et al. 1998).

2.2.1.3 Length of previous sleep
According to a 1998 review there were then no studies on the effect of length of previous sleep specifically on driving performance (Smiley 1998). For most people, however, getting two hours less sleep than needed is enough to consistently impair performance the next day (Gander, Waite et al. 1998). Other studies estimate that less than six hours of sleep prior to the shift increases the risk of a crash by four-fold (Tasca 2006; Hartley 2007), and less than four hours of previous sleep by 19-fold (Tasca 2006).

In some countries it is common for truck drivers to drive in pairs, and for one driver to sleep in a berth behind the driver’s seat while the other drives. These so-called split-shift arrangements are particularly common in the USA, where the length of the last sleep period is typically four hours. Where sleeper berths are used to split sleep, the risk of fatal crash has been found to increase by three-fold (Smiley 1998).

2.2.1.4 Cumulative sleep deficit
A less than required amount of sleep over several nights results in a cumulative sleep deficit that can result in severe driver performance decrements (Arnold and Hartley 1998). One study of 18 drivers suggests a reduction in truck driving performance due to cumulative fatigue after four consecutive days of truck driving, with other studies suggesting that a similar deficit leads to increased accident risk (Smiley 1998). A separate longitudinal study demonstrated that less than 12 h sleep in the previous 48 h period results in increased risk for a fatigue related incident (Williamson, Lombardi et al. 2010).

Across several countries, truck drivers taking multiple consecutive shifts are more likely to report fatigue problems (Mitler, Miller et al. 1998; Adams-Guppy and Guppy 2003).

2.2.1.5 Recovery from sleep deficit
Data from a large Canadian study of truck drivers suggested that a “reset” period of 36 h following sleep debt cumulated over several days of driving is not effective. Many drivers continued to sleep poorly during the recovery period and did not get the sleep they were reported to require (Vespa, Wylie et al. 1998).

2 This is dealt with under organisational considerations.

While some studies suggest that it takes two good nights for sleep to return to normal after sleep loss, one study on drivers who took consecutive night shifts showed that even 60 h off-duty was not enough to eliminate the sleep debt accumulated (Gander, Waite et al. 1998; Boivin 2000). More recent work stresses the importance of considering longer term sleep history on recovery rates, suggesting that recovery from sleep debt takes longer if the debt has been built up chronically rather than acutely (Rupp, Wesensten et al. 2009).

In summary, current evidence on actual sleep obtained by the driver suggests that an undisturbed, extended and routine night-time sleep is important in preventing fatigue, and that sleeping environment may play a relatively minor role.

The actual length of sleep required will vary from individual to individual, and this is a particular challenge for managers. Nevertheless obtaining at least six hours appears to be important. Sleep experts agree that most adults need 7.5 to 8.0 h a night to avoid a cumulative sleep debt (Gertler, Popkin et al. 2002). Evidence based on 'work-enforced' cumulative sleep debt implies that drivers who either do not get enough sleep over several nights, or attempt to recover from a cumulative sleep debt with only one night of sleep, will face high levels of fatigue risk on their next duty.

2.2.2 Individual differences

The importance of accounting for individual differences has been well highlighted by recent naturalistic driving studies (Backer-Grøndahl, Phillips et al. 2009). Based on the systematic rating by trained observers of videos of 41 drivers' faces across thousands of hours of naturalistic driving, it was found that less than ten per cent of the drivers (accounting for only seven per cent of the total driving time) accounted for 39 per cent of high-drowsiness episodes (Knipling 2005). These drivers were over 25 times more likely than the other drivers to suffer a drowsiness episode, independent of driving occasion, roster or organisation.

Several other studies are supportive of large variation across and within individuals with respect to proneness to fatigue and fatigued driving (Knipling, Boyle et al. 2004). Although rigorous studies aiming to identify how demographic differences account for such results are lacking (De Milia, Smolensky et al. 2010), findings are available on how sleep disorders; age and experience; drug use; diet; and exercise influence fatigue levels in occupational drivers.

2.2.2.1 Health disorders causing fatigue

Normal healthy sleep is continuous, with regular architecture. Several health conditions disrupt this pattern and cause excessive daytime sleepiness.

Insomnia is difficulty getting to sleep and staying asleep. It can be the result of stresses in everyday life or a traumatic event, and is often related to common psychological disorders such as anxiety or depression (Knipling, Boyle et al. 2004).

Obstructive sleep apnea (airway obstruction) affects five to ten per cent of the normal driving population (Smiley 1998; Hartley 2007). It is a highly prevalent disorder in commercial drivers, with 18 per cent of US commercial license holders estimated as having mild sleep apnea. One study even estimates that 71 per cent of a truck driving population had sleep apnea to some degree (Knipling, Boyle et al. 2004; Czeisler, George et al. 2009; Smiley, Smahel et al. 2009). Obesity may increase the onset of apnea in commercial drivers.

Other sleep disorders, which can be rarer but more serious, include restless leg syndrome, periodic limb movement disorder and narcolepsy (Caldwell and Caldwell 1998; Gertler, Popkin et al. 2002). A rarer but relevant disorder is the little investigated sopite syndrome, which is physiological reaction to motion (Brill, Hancock et al. 1998).

2.2.2.2 Age and experience

The demographic factor most consistently affecting sleep patterns is age.

First, older workers are more likely to have trouble sleeping and suffer from sleep disorders (Holland and Leutzinger 2003). There is also some evidence that drivers over 45 are more susceptible to fatigue, but in practice this may be countered by better management of job demands that drivers gain with experience (Brown 1994).

Second, there may be a tendency for more young and inexperienced drivers to drive while fatigued. One study found that percentage reported accident involvement during a single year was more than double for drivers with less than five years experience than those with 15 or more years experience [cited in (Elvik, Høye et al. 2009)]. Naturalistic observations in the US appear to confirm that younger, less experienced drivers have a greater tendency to drive fatigued (Barr, Yang et al. 2005).

Together, the studies relating fatigue to occupational driver age suggest drivers near the start or end of their careers may be particularly vulnerable.

2.2.2.3 Lifestyle

Many drivers ingest caffeine in tea, coffee, colas or other drinks. Research shows that the drug has short-term benefits in terms of increased alertness (Gertler, Popkin et al. 2002). However, tolerance to its effects develops with use, and excess use can result in performance decrements. Worse still, consumption within four hours of a main sleep may disrupt sleep and cause further dependence on caffeine during waking hours (Gertler, Popkin et al. 2002) .

A balanced diet can help reduce fatigue, and ward off illnesses that can induce insomnia. The midday meal is important to maintain afternoon alertness as breakfast is to maintain morning alertness. Too much carbohydrate in a meal can induce serotonin, which causes sleep, while protein can trigger dopamine relaese to induce alertness. Dehydration can cause fatigue. More fatigue has been found among drivers not limiting alcohol intake the night before driving (Adams-Guppy and Guppy 2003).

Exercise may not make a difference to those who already sleep well but may benefit those who have problems sleeping. More research is needed to identify optimum time before bed that exercise should be taken (Gertler, Popkin et al. 2002).

Finally, a particular problem for many drivers is also that they may often not know that medication they are using for health complaints increase sleepiness.

There are many other individual differences affecting fatigue, including gender, preferred peak activity times (“larks” versus “owls”), attitudes to fatigue and wake-time activities grounded in personality or upbringing, or hardiness (Furnham 2005). *Those we have listed suggest that managers may wish to consider screening and treatment of sleep apnea and general health; encouraging a healthy lifestyle; and those fatigue risks particular to younger and possibly older drivers.*

2.2.3 Psychosocial pressures at home (family, friends, hobbies and interests)

Fatigue is usually studied as a physiological phenomenon with chronobiological determinants, and there are some claims that psychosocial determinants have been neglected. Social life at home will affect the amount of sleep a driver gets, the nature of their activities outside of work, and thus how fit they are for duty (Fletcher and Dawson 2001; Dawson, Noy et al. 2010). According to Dawson & McCulloch (2005), "*changes in (…) social use of time in and outside the workplace have exerted downward pressure on the amount of time individuals choose to allocate for sleep*". Such pressures may help explain the surprisingly weak correlations between sleep opportunity and measures of sleepiness and fatigue found for drivers in operational conditions (Fletcher and Dawson 2001).

<u>To fully understand the pressures causing fatigue, managers need to consider that there are physiological and psychosocial influences on driver fatigue that will transcend all aspects of life i.e. not only work-time activity.</u> One way to address psychosocial pressures outside of work would be to increase understanding of driver fatigue among friends and families.

2.3 Organisational level influences on fatigue

2.3.1 Scheduling

When employers create a schedule, they effectively determine three important influences on fatigue:

1. time on task;
2. time of day task is performed; and
3. opportunity for sleep.

2.3.1.1 Time on task

Driving is a task that demands sustained effort under conditions that are often perceived as monotonous. It is therefore inherently tiring. Thus the length of time scheduled for the driving task seems important – the longer one drives, the more tired one becomes, and the greater the risk for an accident.

This notion is supported by some research (Feyer and Williamson 2000). For example, an Australian study shows that 17 h of sustained wakefulness produces decrements in hand-eye coordination equivalent to a blood alcohol level of 0.05 per cent (Dawson, Lamond et al. 1998). A classic US study involving 18 drivers suggested that drivers started to feel fatigued about four to five hours through the completion of standard length trips of ten hours (Mackie and Miller 1978). The same study proposed that these self-reports of fatigue were in line with a changeover from a lower than average to higher than average accident rate occurring after five hours. More recent studies supported that truck driver feelings of fatigue increase in line with time on task (Arnold and Hartley 1998).

However, other studies question whether driving within or close to hours of work legislation limits would cause performance decrements. Several studies carried out after Mackie & Miller (1978) suggest that accident rates do not increase until after 8 hours into a truck trip (Smiley 1998). Other studies suggest it is possible to increase a one-off trip length to 16 h for well-rested drivers, with no significant detriment to performance levels, as long as there is sufficient time for recovery afterwards (NTC 2006). Other studies on the effect of fatigue on actual crash risk find that there is increased risk only after 6 h of driving (Brown 1994). A summary of eight studies evaluating the effects of individual aspects of regulation on truck and bus drivers shows that accident rates increase substantially only after 9 hours of driving without a break. (Elvik, Høye et al. 2009). Moreover, 62 per cent of truck drivers involved in fatigue accidents said they had driven less than 100 miles when the accident happened (cited in (Adams-Guppy and Guppy 2003)), and a recent naturalistic observation of truck drivers suggested that fatigue-related events were more likely to occur during the *first* hour of driving (Barr, Yang et al. 2005), implying that fatigue effects of sleep intertia may be at least as important as those from time-on-task.

<u>Together the research suggests that although drivers may begin to feel fatigued after a few hours of driving, there is little evidence that time on task within the confines of driving hours legislation results in a decrease in performance or safety levels.</u>

2.3.1.2 Time of task

Natural light-induced hormonal changes affect how tired we feel at certain times of the day. These so-called circadian rhythms produce two main troughs in alertness, one in the early morning, between 01:00 and 08:00 h, and one in the afternoon, between 14:00 and 18:00 h. The latter can be exacerbated by post-lunch dip in blood sugar 3 to 4 hours after eating, but the early morning dip is recognised as more pronounced (Brown 1994; Gertler, Popkin et al. 2002).

Time of day has been found to be a far better predictor of decreased driving performance than time on task (Arnold and Hartley 1998; Smiley 1998). One study estimates that the early morning trough increases risk of a fatigue accident by up to ten times (Brown 1994). A large US 1996 study of 80 drivers and more than 4000 hours of driving over 200,000 miles concluded that peak drowsiness occurred during the eight hours from late evening until dawn, and in comparison hours of driving was not a strong or consistent predictor of fatigue (Tasca 2006).

In another naturalistic study, trained experimenters rated video recordings of driver's faces at the time of critical incidents, and found that driver drowsiness peaked in the afternoon and at night (Dingus, Neale et al. 2006).

Dawn driving has been assessed as particularly dangerous, with a four-fold risk for occupational drivers (Hartley 2007). One study finds that accidents are seven times more likely to occur during the hours of midnight and 08:00 h than at other times of the day, with the highest risk period between 04:00 and 06:00 h. A Swedish study determines that the risk of a single vehicle truck accident increases by 3.8 between the hours of 03:00 and 05:00 (Smiley 1998).

Thus the time that the manager chooses to schedule the driving task is documented to have an effect both on driver fatigue *and* on incidents associated with fatigue in operational environments.

2.3.1.3 Sleep opportunity

In delimiting sleep opportunity, it is important that managers consider several factors.

First, whether the opportunity for sleep is long enough. Is there really enough time for the driver to travel home, rest and sleep, and travel back to work again?

Second, managers must consider at what time of day the sleep will be taken by the driver. Sleep taken during the daytime is interfered with by metabolism and as a result is of poorer quality. Sleep length also falls to about 4.5 h for morning to noon bedtimes (Åkerstedt, Folkard et al. 2004). Sleep beginning at 22:00 h is most recuperative (Smiley 1998). Shiftwork therefore affects the ability to obtain sleep and helps explain why one study finds that nightshift workers have two hours less sleep on average than the corresponding day worker (Hartley 2007).

Third, the manager should consider whether the sleep is routine and predictable, or whether it continually changes in forward or backward rotation.

2.3.2 Job design

According to job design theory, the nature of the task, task variety, task meaningfulness, level of autonomy and level of skill required are important factors influencing motivation, safety performance and wellbeing (Furnham 2005). Since a driver who is motivated, safety conscious and well is more likely to be fully rested and fit for duty than one who is not, it is likely that job design factors will influence the level of fatigue found among drivers.

The effect of non-driving tasks (task variety) on the level of truck driver fatigue has been studied. A simulator study shows that loading tasks performed throughout the day can increase fatigue above that due to driving alone (cited in (Boivin 2000)). However, a recent naturalistic study suggests non-driving tasks may be stimulating rather than fatiguing for local/short haul drivers (Hanowski, Wierwille et al. 2003).

The less control a driver perceives he has over his work, and the less support he perceives he receives will be detrimental in terms of stress, wellbeing and fatigue (Parker 2002). Studies show that drivers with little control can be intimidated by dispatchers to accept unreasonable delivery demands, a factor which increases the risks of fatigue (cited in (Arnold and Hartley 2001)). Other studies suggest more directly that driver control affects fatigue. If drivers cannot choose when to take their breaks, for instance, they must be taken at times that are "unnatural" for the driver and suboptimal in terms of fatigue prevention (Brill, Hancock et al. 1998; Feyer and Williamson 2000). Indeed, driver fatigue has also been shown to be lower for drivers given more autonomy by managers to save shorter legs of the trip for later in the shift (Arnold, Hartley et al. 1997; Adams-Guppy and Guppy 2003). Similarly a multinational truck driver survey reported found that drivers perceiving that management were not supportive about break-taking reported more fatigue problems (Adams-Guppy and Guppy 2003). In the latter study drivers reporting that they were less involved in and satisfied with their route planning also reported more fatigue.

According to both sociotechnical and job design theories, a task is best managed if it is (i) controlled at source; and (ii) visible as a whole to whoever is managing it (Clegg 2000; Clegg and Spencer 2007). Since the only people in a transport company who have complete oversight over the factors influencing driver fatigue are the drivers themselves, we might expect that they are the best placed to manage it. This requires that the organisation empowers them to carry out the task, something which demands that managers trust their drivers enough to give them the control they need, and supplement this control with resources in terms of knowledge and feedback about their fatigue (Clegg and Spencer 2007).

2.3.3 Safety culture

Concerning safety culture, driver perception of colleague norms, both in terms of what a driver perceives that other drivers do and value, are important determinants of whether a driver will stop and sleep on becoming fatigued, or whether they will be likely to ensure that they get enough sleep before a trip (Furnham 2005). Driver training, management commitment to safety, and driver safety input have been found to be important determinants of safety culture in truck companies (Arboleda, Morrow et al. 2003). Studies in other organisations show that employee autonomy increases organisational commitment, which is an important prerequisite to a strong safety culture (Parker, Axtell et al. 2001).

According to work in the field of safety climate, we can expect that policies, management commitment and procedures, citizenship behaviours, and cooperative and proactive safety activity among drivers will also improve fatigue outcomes (Griffin and Neal 2000). However, we do not know of any relevant work that has been carried out directly on truck driver fatigue.

2.3.4 Employee health and wellbeing

Our consideration of individual level influences on fatigue, above, suggests that organisational-level screening for health disorders that can exacerbate fatigue, followed by non-punitive treatment for individuals found to have problems, would be beneficial to the employee and the organisation.

2.3.5 Job competencies

One of the ways organisations can control the large differences in on-the-job fatigue levels found across individuals is by selecting for drivers using behaviourally-anchored competencies describing (i) pro-activeness concerning health and safety; and (ii) normal sleep habits and fatigue response.

2.3.6 Physical environment

Dispatchers and drivers have a certain level of control over the type of roads that they use, which may in turn effect how fatigued they become while driving. Drivers are more likely to withdraw attention from the external environment on undemanding roads (Brown 1994).

The monotony of the road on which the driver drives may have particular importance for fatigue development in long-haul trucking. A recent naturalistic observation of 900 h of truck driving showed that it was one of the main factors associated with fatigue events, along with time of day and sleep history (Barr, Yang et al. 2005; Larue, Rakotonirainy et al. 2009). An audit of crashes in the UK estimated the number of crashes due to fatigue as ranging widely depending on the type of road (Williamson, Lombardi et al. 2010).

Short haul truckers, on the other hand, rate traffic volume as a greater fatigue factor than road type (Friswell 2009).

2.4 Factors interact to cause fatigue

There is little evidence that any one cause of fatigue *in isolation* has a clear effect on performance of the occupational driver (Williamson, Lombardi et al. 2010). It seems rather that a system of factors interact to cause driver fatigue. It is this system and the dynamic interaction of its elements that must be managed by organisations wishing to ensure that the performance and wellbeing of their drivers is not influenced unduly by fatigue.

One of the most important interactions is that between time of day at which task is carried out and both sleep deficit and time-on-task (Brown 1994). For example, a recent study suggests that both a 28 h sleep deprivation and time of day affect driving performance, but only in combination (Williamson and Friswell 2009). Another study finds that truck drivers who begin shifts at midnight and end at 10:00 h, face an increase in crash risk after consecutive days of driving that is far greater than that seen in day drivers driving the same length of shift (quoted in (Hartley 2007)). A recent real-world driving study demonstrated a dose-response relationship between duration of driving and impairment from nocturnal driving (Sagaspe, Taillard et al. 2009). It has also recently been pointed out that the evidence for a pure circadian effect is not straight forward, with most peaks in accident risk occurring earlier than circadian troughs, because studies have not adequately controlled for time-on-task effects (Williamson, Lombardi et al. 2010).

The effect of sleep deficit on fatigue outcomes is exacerbated if the time of day of recovery sleep is not optimal, and this interaction is important in chronic fatigue. One field study finds that many drivers were fatigued before a trip began because they did not recover from workload over the last week, in which night work, short bursts of sleep, and daytime sleep were particularly prevalent (Feyer and Williamson 2000).

Other interactions include those between age and health, and age and lifestyle (Holland and Leutzinger 2003). Naturalistic observation of drivers offers a promising way to be able to study the effects of observable interacting factors such as circadian rhythm and road type (Dingus, Neale et al. 2006; Backer-Grøndahl, Phillips et al. 2009).

Once the causes of fatigue have been considered, managers will need to justify any programme for the management of fatigue. To do this they will need to account for how those causes interact. They will also need to know the nature of any fatigue-related problems particular their organisation. Once a programme is in place, they will need to measure how well fatigue factors are being managed. In other words, in addition to influences on fatigue, managers must also consider which fatigue outcomes are most important to their organisation.

2.5 Outcomes of fatigue

It is generally accepted that continued driving in a fatigued state results in "*progressive withdrawal of driver attention from road traffic demands, either general or selective, but in either case involuntary and almost impossible to resist*" (Brown 1994). Fatigue leads to involuntary reductions in cognitive or muscular performance affecting skills such as monitoring behaviours, vigilance and reaction time. There is an increased tendency to make errors of omission and commission in fatigued drivers, initially seen as slips (e.g. select wrong gear) but eventually mistakes (e.g. misjudge distances) (Brown 1994). If the driver does not stop, the eventual outcome of fatigued driving is sleep.

The above events ultimately lead to increased risk that the driver will be involved in a near miss or accident. Experience with drink driving shows that even small differences in driving performance can lead to large changes in accident numbers (Smiley 1998). Over the longer term fatigue will affect organisational outcomes connected with health and wellbeing, such as driver absence and employee turnover.

A useful way to classify fatigue outcomes is according to whether they are explicit or implicit.

Explicit fatigue is felt subjectively, either mentally (motivation, cognition or affect) or physically, and can therefore be rated by the drivers themselves. Specialised self-report scales have been developed to measure explicit fatigue. One popular self-report instrument is the Karolinska Sleepiness Scale (KSS), in which drivers can choose one of seven items describing increasing sleepiness that best describes their current subjective state (Åkerstedt 1990). Although useful and informative, the reliability of self-reports as stand-alone measures of fatigue is often questioned, with some authors finding that subjective estimates of alertness and sleep quality are not well correlated with objectively reliable fatigue outcomes (Smiley 1998). Subjective ratings may also suffer from lack of sensitivity, with some studies suggesting performance decrements may be exponentially related to subjectively felt increases in fatigue (Dawson and McCulloch 2005). One way in which explicitly felt fatigue can approximated objectively is using EEG devices to measure psychophysiological changes. However, this technology is not yet practical enough for organisations to use in driver fatigue management.

Implicit fatigue is apparent indirectly, most usually in driver behaviour, driver performance or in the results of that performance. Measures of implicit fatigue are often taken in addition to subjective reports. They are in any case often of greater interest to the organisation than explicit fatigue.

One commonly used behavioural measure of fatigue is the psychomotor vigilance task (PVT). Different types of task can be presented on portable computers. The most common measure any decrements in response time or monitoring behaviours that are due to fatigue.

Measures such as percentage eyes closure (PERCLOS), eye movement, facial tone, lane drift and steering movements showed great promise as measures of implicit fatigue in simulator studies (Knipling 1998), and some of these measures have already been employed in naturalistic observation studies (Kecklund 2009). PERCLOS in particular has proved a promising correlate of fatigue in pilot projects (Wilschut, Caljouw et al. 2009). However, it remains true to say that none of these individual measures can be considered robust and reliable enough for general field use. Attempts are ongoing to combine different measures in order to increase reliability of individual measures (Bowman, Hanowski et al. 2009).

Measures of implicit fatigue of ultimate interest to organisations and regulatory bodies are fatigue-related accident or near miss analyses. However, it is notoriously difficult for accident investigators to identify fatigue as a cause of an incident or accident in the absence of a definitive post-crash marker of operator impairment, and there have been several calls to improve the way police and employee organisations collect data in order to ease identification of fatigue factors (Arnold and Hartley 1998).

Other organisational outcomes may also be important measures of implicit fatigue. These include costs due to lost productivity, absenteeism, turnover, reduced morale, increased wear and tear on equipment, and health records (Gertler, Popkin et al. 2002).

Despite the array of explicit and implicit fatigue outcomes considered, no measure is available that varies exclusively with fatigue. Indeed the absence of an objective and reliable index of fatigue is one reason why managers have not appeared to grasp that fatigue is a serious problem for their drivers (Dawson, Lamond et al. 1998). To understand the effects of fatigue requires therefore that several measures are employed together. These measures must often be collected at both individual and organisational level, and where possible be related to measures of fatigue causes or fatigue risk. The implication, then, is that the organisation needs not only to understand, manage and possibly measure those factors interacting to cause fatigue in their employees, but also to monitor a set of fatigue outcomes in order check that fatigue is being managed, and respond accordingly if it is not.

2.6 Summary

Fatigue is recognised as a major cause of crashes involving occupational drivers. A review of research on fatigue in occupational driving suggests influences at individual and organisational levels. In particular the interaction of the following influences should be considered:

- Sleep – length of last sleep; time since last sleep; amount of sleep over last few days; time sleep taken; time to recover from lack of sleep

- Schedule – including normal length of shift, time of shift, recovery intervals, sleep opportunities

- Individual differences – particularly age and experience, general health, sleep disorders, individual preferences

- Psychosocial influences at work – e.g. peer attitudes, peer behaviour, level of management trust, safety culture

- Psychosocial influences at home – family, friends, hobbies and interests
- Length of commute
- Job design – e.g. level of control in counteracting fatigue, knowledge and feedback about fatigue
- Employee selection

The successful understanding and management of fatigue in an organisation will require the monitoring of at least some of these influences in relation to the following outcome measures:

- Driver reports of own fatigue – response scales, diaries, logs
- Behavioural measures of fatigue (monitoring of physiological indicators of fatigue, cognitive testing, driver performance on the road)
- Organisational outcomes –incidents, near misses, accidents, turnover, absenteeism, health

3 Tackling the causes and outcomes of fatigue at organisational level

An organisation can operate at four levels to reduce the chance that accidents are caused by fatigue in its drivers. It can:

1. Reduce the severity of the consequences of poor driver performance resulting from fatigue;
2. Prevent a fatigued driver falling asleep behind the wheel;
3. Prevent the driver becoming fatigued while driving; and
4. Prevent the driver getting into the vehicle in a fatigued state.

A consideration of how fatigue can be dealt with at each of these levels leads to a discussion of how fatigue can best be managed by organisations.

3.1 Reducing the consequences of fatigue in driving

Road authorities are usually the only organisations that can tackle the problem at this level. They can do this by altering the road environment using profiled lane marking, rumble strips or divided highways. The aim is to reduce the seriousness of the consequences of sleepiness at the wheel (Phillips and Sagberg 2009). They can be effective in terms of accident reduction (Hickey 1997; Phillips and Sagberg 2009), but while they do not prevent all personal or material damage resulting from fatigue, extra measures are needed to prevent drivers becoming fatigued.

3.2 Preventing the fatigued driver falling asleep behind the wheel

Eye closure, microsleeps and sleeping are the most hazardous effects of fatigue for the occupational driver. As mentioned already, it is now clear that sheer will power will not prevent a severely fatigued driver from sleeping (Brown 1994; Hartley 2007). Measures to prevent fatigued drivers from falling asleep behind the wheel are therefore highly desirable.

One approach is to persuade drivers to stop and rest when fatigued, in order to give a short term increase in alertness and help the driver reach their destination safely. Several road authorities have introduced sign-posted roadside rest areas, and accompanied their introduction with roadside or national media campaigns (CAST 2009). Another approach is to communicate the importance of stopping at meetings between police and drivers at truck stops (Jettinghoff, Staren et al. 2005). There are not enough "stop-and-rest" campaigns to be able to summarise the overall effects on accident outcomes (Phillips, Ulleberg and Vaa, 2009). However, there are three reasons to be skeptical about this approach.

Firstly, it fails to consider that the occupational driver often has delivery deadlines and prescribed rest times. Indeed there is evidence that occupational drivers continue driving when they know they are fatigued because they want to reach their destination (Boivin 2000). This may explain a severe mismatch between what drivers know about sleep (i.e. that it is important to get enough before a trip) and what they manage to do (Arnold and Hartley 1998).

Secondly, there is evidence that drivers overrate their ability to cope with fatigue. One study reported that ten per cent of drivers rated fatigue as a problem for them individually, but the same drivers rated fatigue as a problem for 36 per cent of other drivers (Hartley 2007). Evidence from Norwegian car drivers even suggests that drivers are aware of the fatigue problem, can identify the symptoms of fatigue and are even good at ranking the most effective countermeasures, but still continue to drive or employ ineffective countermeasures when they experience the symptoms (Nordbakke and Sagberg 2007). These findings are also reflected in a recent large-scale truck driver study in the US (Dinges 2009). Given these findings, general campaigns that merely raise the awareness of the problem or inform about what to do to tackle fatigue would presumably have limited effect.

Thirdly, several reports find that campaign effects on accidents are enhanced if they are accompanied by police enforcement (Delhomme, Vaa et al. 1999; Phillips, Ulleberg et al. 2010). However, it is hard to measure fatigue and therefore difficult to punish drivers who continue to drive fatigued (Carson 2006).

Most strategies used by drivers to counter fatigue once it has developed are short-lived and not well validated. These include physical activity, sitting in an uncomfortable position, controlled noise, interaction with workmates, fresh air, snacking, and increasing the lighting (Boivin 2000). Better validated but nevertheless short-lived strategies include drinking coffee and a sudden reduction in ambient temperature for between four and eight minutes (Boivin 2000).

According to the Energy Institute, the only effective countermeasuress against fatigue once it has developed are a well-planned journey, napping and caffeine (Gall 2006). However, the use of caffeine can contribute to sleep loss if taken by a driver to help them reach a rest area (Queensland:Government 2009). Commonly used strategies, such as opening a window, listening to the radio, resting without sleeping or exercising are considered ineffective.

Strategic napping has been shown to assist maintenance of alertness levels in cases where the sleep debt is not too high. Policy guidelines on napping have been issued in Australia, where preventative and operational naps are described and delimited, according to research findings (Hartley, Buxton et al. 2008). However, most guidance stresses that napping should only be used to improve alertness and not as a way to restore sleep. Its negative effects (sleep intertia; disruption of main sleep) must also be considered (Boivin 2000). Some authors claim that a nap of less than 90 min (the time needed for a sleep cycle) will not prevent the onset of fatigue (Gertler, Popkin et al. 2002). Policy makers should also consider the difficulties many people have with napping, such as getting to sleep and waking once asleep (Imberger, Styles et al. 2006). Napping that comes just before work may be more beneficial than napping that occurs throughout a duty-period as desired (Gertler, Popkin et al. 2002).

Some authors claim that stimulant, hypnotic or blue light interventions must be more strongly considered for drivers, and that they are temporarily effective ways to help drivers when they must drive through circadian troughs (Caldwell 2009).

Technologies to alert drivers that they are fatigued, and thus reduce the level of reliance on driver's own rating, have been developed. They can be classified according to whether they are based on (i) physiological measures related to sleepiness e.g. eye closure; (ii) aspects of driving behaviour e.g. steering, lane tracking; or (iii) predictive mathematical models of fatigue informed by prior sleep history and work-rest patterns (Kecklund 2009). Objective ratings of driver sleepiness are now able to predict performance on certain simulator tasks, but much more development work is needed before companies can use them (Smith 2009). All current alertness monitoring devices have their limitations and operational problems and empirical field studies, rather than simulator studies, are required to see whether they can reduce the numbers of fatigue-related accidents (Tijerina, Gleckler et al. 1999). The envisaged ideal is that these technologies would, on detecting fatigue, trigger an intervention to maintain alertness and improve safety outcomes (Balkin, Horrey et al. 2010).

3.3 Preventing the driver becoming fatigued while driving

Here we consider ways to manage those factors that influence how fatigued a driver will become during a drive. These include factors such as choice of road by driver or scheduler, the level of physical activity during the trip (loading/unloading), cabin temperature, meal timing, time of day of trip and length of trip. Restricting the length of the driver's trip using governmental legislation has been the main way in which fatigue has been managed, and its effects are worthy of special consideration.

Most driving hours legislation acknowledges the number of hours per shift, number of hours per week and the minimum length break times. For professional drivers of heavy vehicles in Europe the Drivers' Hours Rules Directive restricts driving to no more than 9 h in any 24 h period, with the possibility of driving 10 h no more than twice a week (Gander, Hartley et al. 2010). Each country within the EU must ratify and incorporate this directive with its own legislation, and with the Working Time Directive[3]. In the USA a Federal law from 1938 restricted work to 12 h of driving or 15 h of total duty in any 24 h. This was surpassed in 2003 by a rule that reduced each maximum period by a further hour. This was, however, struck out by a Federal ruling in 2007 (Gander, Hartley et al. 2010). In Canada the equivalent limits are 13 h of driving and 14 h total duty, and in New Zealand 13 h of driving and 13 h of total duty.

Hours of work legislation can also be described at organisational level. Examples are BP's *Driver' hours rules* and Shell's *Limitations on driving and duty hours* (Holmes, Baker et al. 2006). Shell's rules stipulate no more than 12 h of duty

[3] In Europe, national driving hours legislation must comply with the European Commission Working Time Directive, which states that employees have the right to refuse work more than 48 h per week; have daily rest periods of 11 consecutive hours in each 24-hour period; and a minimum weekly rest period of one day in any seven days.

(driving and non-driving work) in any 24 h period; no more than 9 hours *of driving* in any 24 h period; and no more than 4.5 h driving without a break.

Hours of work legislation is often enforced through auditing of driver logbooks or tachnographs, which register the time a driver's vehicle spends moving (Moore 1998).

Legislation has been criticized for disregarding scientific findings on the substantial effect that time of day has on fatigue, performance and accidents (Fletcher and Dawson 1998). In some countries legislation has recently been modified to account for this (Jettinghoff, Staren et al. 2005; Hanowski, Hickman et al. 2009).

There are several other important criticisms, however. Most legislation fails to control for either chronic fatigue effects or considerable variability in fatigue proneness within and between individual drivers (Haworth 1998). Thus even though a driver may be severely fatigued – due to an interaction of health, lifestyle and occupational factors, for instance – as long as they drive according to prescribed hours of work, managers can be said to have performed their duty. The widely varying interpretation and application of regulations by increasingly competitive road haulage industries is also criticised (Haworth 1998). In Australia logbooks have been criticised as unrepresentative of the driver's actual activities. Even where tachnographs are used, legislation is rarely enforced rigorously (Mahon 1998; Hartley 2007). This may be one reason why little difference was found, in terms of either actual driving hours or fatigue-related safety outcomes, between non-regulated and regulated states in Australia in the 1990s (Haworth 1998; Poore and Hartley 1998; NTC 2006).

Other studies suggest that hours of service restriction has little effect. The 2003 update of hours of service legislation in the USA was carried out to account for research showing a large number of truck drivers were getting an average of less than 6 h sleep a night (Backer-Grøndahl, Phillips et al. 2009). The effect of this legislation was evaluated in a naturalistic driving study involving 82 drivers from three companies (Hanowski, Hickman et al. 2007). The study found a slight increase in the average nightly sleep drivers were getting, but there was no evidence of a decrease in fatigue related driver behaviour.

Hours of service paradigms are also criticised for legalising sleep opportunities at times of day when sleep is difficult to obtain (Moore-Ede, Heitmann et al. 2005). A particular problem until relatively recently with US regulations was a lack of synchronisation between the hours of service prescribed (10 hours on, 8 hours off) with natural 24-hour circadian rhythms. Drivers were often asked to accelerate their natural sleep patterns under this legislation (Knipling 1998).

As already noted legislation often prescribes minimum non-work times for a given period. A study of truck drivers gives some support for this, showing that the relative accident rate for drivers taking less than 11 hours break a day is 1.2 times greater than drivers taking over 11 hours a day (cited in (Elvik, Høye et al. 2009)). However, the evidence suggests that it is whether this rest is taken continously or interrupted by driving that is important. Drivers with interrupted rest, often taken in the truck, are estimated to have 3.05 times as high a risk of being involved in a fatal accident than drivers who take their daily rest unbroken (Elvik, Høye et al. 2009). Given that existing regulatory frameworks for professional drivers do not address the timing of work and rest and the necessity to obtain adequate sleep (Hartley 2007), this evidence is concerning.

The need for greater flexibility and control than current legislation affords is well summed up by (Holmes, Stewart et al. 2006):

"*Hours of work restrictions are based on broad assumptions and predictions about how much fatigue is experienced by employees (…). They ignore the variation in fatigue risk that occurs from one day to the next, between individuals, across seasons, with different workloads and as roles and experience change*."

Perhaps the most important criticism of hours of work legislation is that, no matter how restrictive it is, prescriptive legislation encourages management of hours of service rather than the management of fatigue and alertness. Many business, risk management, job design and sociotechnical theories would argue for the management of important fatigue outcomes rather than the management of selected fatigue causes (Clegg 2000; Clegg and Spencer 2007; Moore-Ede 2010). They would add that governmental-level management of fatigue is too far removed from the problem to be effective.

Despite the strength of these criticisms, it is worth stressing that one must be careful when removing or replacing such legislation. First, the resulting rules are well understood by the industry, they are consistent and unambigous. Second, a recent careful re-examination of crash data found that crash odds did increase with continuous hours driving, raising questions about the body of studies suggesting a lack of association with crash odds (Jovanis, Chen et al. 2009). Third, some authors claim that we know little about the effects introduction of hours of service legislation on crash odds because proper evaluations are difficult to carry out (Elvik, Høye et al. 2009). We should therefore be open-minded about the positive effects they may have had.

Given these uncertainties it seems wise to recommend that a cautious approach be taken, in which existing legislation is made more flexible and takes better account of driver circumstances (Moore 1998).

In any case restricting hours of service seems to be a good idea given certain conditions: that flexibility is afforded; that restrictions are attended to in practice; and that other fatigue factors are considered and managed simultaneously at organisational and individual levels. Without these conditions legislation will fail to explicitly account for the need to consider the various dynamic and systemic influences on driver fatigue that cause him or her to be fatigued not only during a trip, but before getting into the vehicle.

3.4 Preventing the driver getting into the vehicle in a fatigued state

It is more effective to ensure that the driver gets into a vehicle in a rested and healthy state than it is to counter fatigue while driving, and the only way to do this is to ensure that the driver has obtained enough good quality sleep sufficiently recently. There are various ways to improve the quality and quantity of sleep a driver gets.

Pharmacological methods, mostly involving the use of hypnotics, are approved by authorities regulating aviation in several countries (Caldwell, Mallis et al. 2009). Disadvantages include dependence arising from regular use, side effects and hang-over periods. Non-pharmacological methods, which are undoubtedly more desirable in the interests of a normal, balanced lifestyle, include improving the sleeping environment, healthy sleep practices (extending time in bed; awareness of own sleep by keeping a sleep diary or using actigraph feedback; and natural waking) and exercising. To help drivers with sleep apnea sleep better, there is a simple, safe device available to treat it, and driver compliance can be monitored (Czeisler, George et al. 2009).

Napping before a trip may also help, and has the greatest effect on performance of any countermeasure other than prolonged sleep, lasting up to several hours after the nap (Boivin 2000). Some research suggests that the nap should not be longer than 45 minutes, to prevent grogginess induced by deep sleep (Hartley, Buxton et al. 2008). However, naps are ultimately ineffective in poorly rested occupational workers. Studies of shiftworkers show that naps can improve performance on the first night of a sequence of shifts, but the improvement declines on subsequent nights (Smiley 2006).

3.5 How can organisations manage fatigue?

Ideally, fatigue should be managed at more than one of the above levels by organisations wishing to limit its effects on their operations. We have seen that a transport company will have limited power to prevent the consequences of fatigued driving. Attempts to persuade drivers to stop and rest or manage fatigue as it develops during driving do not appear to be fruitful. It seems therefore that the fatigue management by organisations would be more effective if they were to focus on preventing drivers becoming fatigued while driving, and ensuring they are optimally fit for driving before entering the vehicle.

We saw in Chapter 2 that in developing a programme to manage fatigue at these levels, managers would need to measure and account for a whole system of influences on fatigue, including driver sleep history, driver schedule, individual differences, various psychosocial influences, commuting, job design and employee selection. A comprehensive organisational programme is implied as a way to manage this system of factors and measures, and to evaluate and thereby evolve their effects on fatigue outcomes.

A theoretical example of such a programme is given below for illustrative purposes, using recommendations in the literature and the authors' knowledge of organisational implementations to structure the considerations we have made so far. In particular, available analyses suggest that scheduling and training should be major tools in the management of fatigue (Poore and Hartley 1998; Boivin 2000; Smiley, Smahel et al. 2009). The measures summarised are not exhaustive, and would be selected by the individual company based on the findings of a needs analysis in which subjective fatigue, driver sleep, behavioural indicators of fatigue and/or driving performance were recorded over a period to inform any intervention.

First, create a supportive organisational context:

- Fatigue policy to account for management of fatigue, written procedures, lines of responsibility, analysis and response to fatigue-related incidents and accidents, and selection procedures.
- Ensure safety culture and climate optimal for fatigue management (e.g. pro-active safety behavior in addition to compliance behaviours)
- Ensure those who have the responsibility for controlling fatigue have sufficient autonomy, information and feedback.

Train/coach at all organisational levels to increase awareness and knowledge, change attitudes, intentions and behaviour:

- Survey awareness of fatigue causes and outcomes among managers, drivers or other stakeholders, and attempt to improve as necessary (training)
- Survey manager and/or driver need for theoretical and practical training in tools for fatigue management; countermeasures and coping strategies; address as necessary (theoretical hands-on training; coaching to raise awareness of personal fatigue causes and coping strategies)
- Survey attitudes to fatigue among drivers and managers, and attempt to improve as necessary (e.g. visible management commitment to fatigue policy, training)
- Survey fatigue-related behaviours among drivers, and attempt to improve as necessary (e.g. by training, job redesign, feedback, coaching)
- Survey understanding and attitudes to fatigue among driver's family and friends; attempt to improve as necessary (e.g. training presentation, films, brochures).

Schedule to account for fatigue:

- Avoid chronic fatigue by ensuring employees can routinely obtain an undisturbed, extended sleep, at night (scheduling).
- When night driving is not avoidable, ensure the driver us well-rested before attempting to drive between midnight and 06:00 h (scheduling); minimize the number of sequential night drives as much as possible.
- Account for commuting to and from work in scheduling; address fatigue on commute home.

Address how health influences fatigue:

- Monitor for general health and sleep disorders; respond and treat non-punitively.

- Encourage a healthy lifestyle, diet and sleeping habits (e.g. subsidise healthy food at work)

- Consider shiftworkers, inexperienced drivers, drivers with general health problems (especially older drivers), and drivers with sleep disorders as high-risk groups

The emphasis on scheduling to account for fatigue implies that the transport company will have a certain level of control over their schedules. Some authors claim that companies have considerably more control over their schedules than is widely recognized (Feyer, Williamson et al. 2001). However, Caldwell & Caldwell (1998) claim that in a society of 24-hour customer demand, stressful long hours and rotating work shifts are unavoidable, and the focus should be on treating sleep disorders and encouraging drivers to choose to sleep more, by giving them knowledge about how to reduce stress and by raising awareness of the dangers of voluntarily restricting sleep. It does seem to us that the adjustability of a schedule will in most cases have to be reconciled with operational factors by managers, and will therefore be limited.

Where a schedule is adjustable, the ideal is to be able to predict, measure and restore any possible sleep debt occurring in the average driver across a duty cycle by ensuring that proper restoration is possible, and that it preferably takes place at night. Several software programmes are now available that use biomathematical models to help managers schedule in a way that is optimal in terms of sleep restoration (see Box 1 in the next Chapter). Using these it is now possible to design schedules that will control acute fatigue in the average driver, but more work needs to be done to attend to chronic fatigue resulting from the history of work/rest patterns over the preceding days and weeks . Another problem for such approaches is that they are normally based on predictions of how much sleep drivers will obtain in a given sleep opportunity, but managers do not usually know how much sleep their drivers get when they are off duty.

In addition to training and scheduling, <u>our analysis also stresses the importance of understanding and addressing organisational influences on fatigue management, such as job design or safety climate</u>. In particular a body of research in organisational psychology suggests that any fatigue management effort would do well to <u>ensure the driver has sufficient flexibility to control own work / break patterns (autonomy),</u> and this is supported by studies in occupational fatigue (von Thaden and Gibbons 2008; von Thaden, Spain et al. 2009) (Feyer, Williamson et al. 2001) (Warr 2002). Autonomy allows drivers to respond to normal but unpredictable variation in driving assignments (e.g. fatigue-inducing driving episodes caused by weather problems or traffic) and to accommodate individual differences in the need for sleep and rest. <u>An important part of this self-management is feedback</u>, which allows fatigue to be managed in a way that is responsive to the level of fatigue in the individual driver. It is possible to distinguish between two forms of feedback. Feedback about sleep quantity and quality, and on-line feedback about alertness while driving.

<u>Given the need to design jobs and manage people in addition to schedule analysis and training, managers have an increasingly important role to play in managing</u>

fatigue. Regulatory authorities in some countries are therefore increasingly supplementing hours of work approaches by encouraging the continuous management of employee fatigue by transport organisations.

In the mid '90s the state of Queensland in Australia was the first to offer hours of service opt-outs to transport companies demonstrating adequate Fatigue Management Programmes (FMPs). In some countries, such as the UK, New Zealand and again Australia, more recent trends are to stipulate that fatigue should be accounted for and managed as an occupational risk under existing occupational health and safety law. To do this, organisations need to develop a Fatigue Risk Management System (FRMS). As organisations become increasingly aware of attempts made by others in the field to manage the effect of fatigue on operations, formal efforts to manage fatigue are becoming increasingly commonplace.

In the next chapter we describe some of the tools commonly used in FMPs. In Chapter 5 we give a background to FMPs, before considering how they should be evaluated in Chapter 6. An inventory of FMPs is described in Chapter 7.

4 Tools and technologies for managing fatigue at organisational level

The literature suggests several tools that could help managers and drivers effectively manage fatigue, of which training / coaching and scheduling / rostering are perhaps the most widely mentioned.

4.1 Training / coaching

Safety training has been linked to increased safety knowledge, which in turn predicts compliance with safety policy (Griffin and Neal 2000; Arboleda, Morrow et al. 2003). Since fatigue is a key safety factor for occupational drivers, knowledge about its causes and effects may improve understanding and compliance with fatigue policy. Drivers may also benefit from learning about effective strategies to increase alertness, about proper regimens of diet and health, and about the consequences of sleepy driving. There is also a need to inform managers about the evidence-based knowledge on how fatigue affects behaviour, and how to account for fatigue in scheduling and rostering. Other stakeholders that might influence a driver's attitude to fatigue can also be educated (e.g. politicians, customers or the driver's friends and family).

Several packages are described in the literature that can form the basis of organisational training to increase knowledge and awareness of fatigue, as well as coping strategies to deal with it, and several have been validated to give increased knowledge and awareness about fatigue in the short term (NHTSA 2002; Rhodes and Gil 2002; Rönicke, Gundel et al. 2005). If used, these materials should be adapted to suit the individual organisation through a training needs analysis (Rosekind, Gander et al. 1996). The training should preferably be based on operational data for that organisation.

The effect of training on driver behaviour or performance is not clear. A summary of the effects of formal skills training of professional drivers across several countries gives mixed results in terms of effect on accident counts, ranging from a 20 per cent decrease to a 45 per cent increase in accident rate, depending on the nature of training (Elvik, Høye et al. 2009).

Formal training is costly, and there may be cheaper options (Elvik, Høye et al. 2009). For instance, a controlled pre-/post-intervention evaluation of various motivational measures on telecommunications drivers found that group discussions reduced accidents by 50 per cent, driver training by 32 per cent and bonuses for accident-free driving by 16 per cent (Gregersen and Morén 1990).

Fatigue is very much an individual experience, and given adequate sleep opportunity, it is ultimately the individual who controls how much rest and sleep they will take. Coaching tailored to individual drivers to help them manage fatigue in a way that suits them best is therefore a potentially valuable alternative approach to more traditional training (Whitmore 2002).

4.2 Scheduling / rostering

Scheduling work and rest to account for fatigue is perhaps the most direct way managers can influence how fatigued their drivers become. Boivin (2000) recommend that schedulers should:

- aim to limit night driving, especially between midnight and 6 am;
- limit the number of night drives to a succession of two or three nights;
- give at least two full nights' sleep after an extended driving period;
- design work schedules around circadian patterns;
- avoid 12 h shifts; and
- preserve minimum 9 h rest periods between shifts, and minimum break periods within shifts.

In addition, rosters should consider rotating drivers between long-haul driving and base duties, in order to account for the need for drivers to sleep at home.

Several tools are now available to help schedulers account for fatigue. Of particular use is software based on so-called biomathematical models (Box 1). These models predict fatigue risk for the "average driver" on a given schedule, using an algorithm that accounts for sleep afforded by and circadian timing of the schedule. Some models (e.g. Three Process Model) also account for sleep inertia. More recently, a simple calculation was published that does not require software and thus allows drivers to predict their own fatigue when and where they want to (Åkerstedt 2010).

Box 1. Modelling fatigue in scheduling

Perhaps the one single measure that has promoted the recent burgeoning of formal fatigue management in transport and other sectors is organisational-based fatigue modelling software.

This software is attractive for managers and regulators responsible for scheduling because it allows them to model the effects of their shift rotors on levels of fatigue using software run with evidence-based mathematical models (DOT 2002; Dawson, Noy et al. 2010). Thus there is no longer a need for managers to comprehend, interpret and apply the findings in the research literature. Rather, they simply enter data on their rosters, and get a fatigue index for teams of operators or the whole organisation. Depending on how the output is formulated, these tools also have the potential to illustrate to managers the human and economic costs of fatigue (Fletcher and Dawson 1998).

Several models have been developed on which to base this software. Each model is based on laboratory-based evidence about the interactive effects of recent sleep/wake periods and the circadian system on sleepiness to attempt to predict the effects of different work schedules on outcomes such as subsequent job performance, fatigue, alertness, vigilance or sleep length (Booth-Bourdeau, Marcil et al. 2005). Commercially available models have recently been classified into two main groups (Dawson and McCulloch 2005). Those based on the early **Two Process Model**, which uses inputs on sleep-wake history and circadian rhythm to predict alertness, and those based on the **Three Process Model**, which was introduced in 1987 to account for an additional third process, the effects of sleep inertia on waking (Åkerstedt, Folkard et al. 2004; Åkerstedt, Axelsson et al. 2007; Åkerstedt, Ingre et al. 2008). Derivatives of the Two Process Model are the **System for Aircrew Fatigue Evaluation (SAFE)** (Dawson, Noy et al. 2010);The **Fatigue Audit InterDyne (FAID)**, currently incorporated into Queensland Transport's FMP implementation guidelines (Dawson and McCulloch 2005; Queensland:Government 2010); and the **Circadian Alertness Simulator (CAS)** (Moore-Ede, Heitmann et al. 2004; Moore-Ede 2010). The latter two have been validated in both laboratory and field studies for their ability to predict sleep opportunity and fatigue risk, respectively. We now turn to consider some of these models in more detail.

Four main factors are accounted for by **FAID**: time of day, history of work and non-work periods, lengths of shifts and breaks, and tendencies to sleep in a given sleep opportunity (Fletcher 2010). Using FAID it is possible to chart predicted fatigue scores at different times of day for different work and non-work periods. Further research is required to inform the FAID model about the contribution to fatigue of a work vs. non-work periods as a function of time before the shift in question, but for the time being reasonable arbitrary estimates can be entered; e.g. Fletcher & Dawson (1998) use a linearly declining function which weights the current hour at 100 per cent and same hour a week ago as 0 per cent. The model can output scores that are easy to understand for managers e.g. ranges can be equated to performance decrements for given percentage blood alcohol concentrations. Fletcher & Dawson (1998) describe an evidence-based fatigue point system, in which low, moderate and high fatigue is set at 0-40, 40-80 and over 80 points, respectively, where 80 points is the predicted level achieved after 21-23 hours of continuous sleep deprivation after five days of work (0900-1700h) and two days off. The developers of this model recognise that it does not take into account important contextual variations such as task differences, and should therefore only be used as a tool to inform managers in combination with risk assessment (Fletcher 2010). FAID software has been used by several organisations in Australia and Canada (Jettinghoff, Staren et al. 2005).

The **Three Process Model** has been validated for its ability to predict subjective ratings of sleepiness, psychomotor performance, and accident risk in simulator driving (Åkerstedt, Folkard et al. 2004). It has also been shown to have some validity in predicting from retrospective bedtime and wake data the risk of actual accident involvement (Åkerstedt, Connor et al. 2008). Attempts have also been made using the Three Process Model to address criticisms that biomathematical models are poor at being able to predict sleepiness at the level of the individual, most being validated for their ability to predict measures averaged for a group. The model's originators claim that the model has 'rather high validity' in being able to predict individual ratings of sleepiness of 16 control room workers, using only start and end of shift times as input (Åkerstedt, Axelsson et al. 2007). Actigraph data, giving start and end of actual bedtimes, only improves predictions marginally. Finally, the model has recently been refined to address a criticism that it accounts poorly for chronic fatigue (Åkerstedt, Ingre et al. 2008), although we do not know of any validations of this version of the model. The Three Process Model has been used in several applications in both research and the field. A recent relation of the Three Process Model is now incorporated into Jeppesens (Boeing) scheduling programme (T. Åkerstedt, personal communication). The Three Process Model is also the basis for the **Sleep, Activity, Fatigue and Task Effectiveness** model, marketed for use with the **Fatigue Avoidance Scheduling Tool (SAFTE-FAST)**, and used by Continental Airlines, US military and Federal Railroad Administration (Hursh and Eddy 2005; Gunther 2008). The SAFTE model has been validated in the sense that it can predict performance on a psychomotor vigilance task (Hursh and Eddy 2005).

The **Fatigue Index Risk Modeule (FIRM)** applies 21 biocompatible principles including clockwise rotation, reducing consecutive work days, minimising early morning starts, reducing shift start time transistions, minimising consecutive work blocks (McColgan and Nash 2009).

A recently developed model, the **Prior Sleep-Wake Model**, is a simple set of rules developed for the rapid assessment of an employee's fitness-for-duty. Fatigue risk can be estimated without the need for software, based on the amount of sleep in the past 24 and 48 h prior to the shift, and the amount of time awake since the last sleep. The prior sleep/wake model attempts to capture and integrate essential elements into a simple algorithm that can be used and understood on the individual level (Dawson and McCulloch 2005). This may be important in empowering drivers to manage their own sleep levels within a given sleep opportunity.

Whatever the model used it is important for schedulers to understand whether the information on sleep/wake periods processed by the model is the actual sleep/wake obtained or is based on inferences about sleep/wake from schedules (Booth-Bourdeau, Marcil et al. 2005; Dawson, Noy et al. 2010). Most testing and validation has been done on actual sleep/wake periods, causing one recent review to caution about the dangers of over-interpretation by scheduling managers of fatigue risks estimated by models making inferences about actual sleep from mere scheduled sleep opportunities (Dawson, Noy et al. 2010).

Models to date have been criticised, both because they estimate sleep indirectly and because they make fatigue risk estimates at the group level (Dawson, Noy et al. 2010). In fairness, the aim of such models is to allow different schedules to be compared and optimised to reduce overall fatigue risk for a group of drivers. There are no claims that the considerable variation in fatigue vulnerability within and between individuals is accounted for. The problem is that there is a danger that the models may be used to justify schedules that may be too challenging for some individuals.

Current models are also criticised for their lack of basis on known effects of fatigue on performance in the specific operational conditions in which the tools are used (Fletcher and Dawson 2001). They also fail to properly account for chronic fatigue build-up when predicting the fatigue risks of a given schedule. A further criticism is that the models cannot account for effects on fatigue of factors such as workload variability or traffic volumes because research in this area has yet to be done (Booth-Bourdeau, Marcil et al. 2005).

Despite these limitations, the models are recognised as useful ways to account for acute fatigue in schedule development. Work has also begun to address several of the above criticisms (Åkerstedt, Axelsson et al. 2007; Åkerstedt, Connor et al. 2008; Åkerstedt, Ingre et al. 2008; Klemets and Romig 2009; Mott, Van Dongen et al. 2009). Moreover, fatigue risk assessments of train driver rosters in Ireland, UK, Australia and South Africa showed not only that the existing roster designs increased fatigue risk, but that operations were protected when biomathematical modelling was used to improve the rosters (McColgan and Nash 2009). Thus there are claims from this and other pilot studies that practicality and functionality of roster redesign based on modelling has been demonstrated.

4.3 Measuring sleep and fitness-for-duty

An actigraph is a wrist-worn computer containing an accelerometer to record movements correlated with sleep/wake activity. Actigraphs are now readily available at relatively little expense (e.g. www.sleepwatch.com). Sleep scores recorded by an actigraph can be input into the above models to predict fatigue risk, or used to inform managers or drivers about the amount of sleep drivers obtain. They are also useful measures in the evaluation of company interventions aiming to improve driver sleep.

Tests of implicit fatigue that can be used to generate performance-based indicators of fitness for duty are also available for use. Several psychomotor vigilance tests (PVTs) can be carried out on small palm-top computer devices by the driver, either before starting duty or once on the road. The PVT gives a relatively robust objective measure for the evaluation of fatigue programmes. PVTs have already proved useful in operational assessments of the effect of different rosters on fatigue in the field (Jay, Dawson et al. 2005), although further validation under operational conditions is desirable.

Bench-top or portable devices are available that monitor pupil characteristics to give instant estimates of driver alertness (e.g. PMI Inc's FIT2000/2500) (Gertler, Popkin et al. 2002; Heitmann, Bowles et al. 2009; Shahidi, Southward et al. 2009) These devices require further validation to show that they measure what they purport to measure.

Neither of the above fitness for duty tests can be relied on without consideration of influences on the test results of factors other than fatigue e.g. caffeine (Balkin, Horrey et al. 2010). It is hoped, however, that data from these devices will eventually be able to be used to calibrate biomathematical software in order to improve prediction of fatigue levels for the individual driver (Balkin, Horrey et al. 2010).

Finally, questionnaires can be used to generate explicit measures of fatigue to help inform managers and drivers about whether it is safe for the driver to embark on the trip (Wilschut, Caljouw et al. 2009). These can be based on measures of subjective fatigue, such as the Karolinska Sleepiness Scale or the Groninger Sleep

Quality Scale, or tailor-made fit-for-duty tests (Wilschut, Caljouw et al. 2009). These tests can also be performed using a portable hand-held computer, perhaps by accessing a website that collects organisational data. As explained earlier, subjective tests are not considered reliable in isolation, and should therefore be used alongside other estimates of fatigue where possible.

4.4 Measuring and assisting driver performance

Once driving, the organisation can assist the driver using various technologies. CoPilot (Attention Technologies, PA, USA) is a dashboard-mounted camera that monitors and gives driver feedback on percentage eye closure (PERCLOS) by detecting infrared reflected from the retina (Dinges, Maislin et al. 2006). Optalert is a similar device made in Australia by Sleep Diagnostics. Technology to detect changes in face muscle tone as an indicator of fatigue are also being developed, and watches that detect and warn the driver about prolonged wrist inactivity could also be useful (Caldwell, Mallis et al. 2009).

To prevent the driver becoming fatigued while driving, devices such as the Howard Power Center Steering System can help reduce the physical effort required to stabilise the vehicle in high winds. The driver can also be assisted by lane tracking devices such as SafeTRAC, which measure steering wheel movement and/or lateral movement of the truck in order to feed information back to the driver on any detriment in lane control.

Whatever the individual technology there remain some operational challenges and validation work (Wilschut, Caljouw et al. 2009). Therefore, to improve the validity of individual instruments, the effects of feedback from a bundle of fatigue management technologies (actigraph, CoPilot, SafeTRAC and Howard Power Center Steering System) was recently studied empirically in 38 US and Canadian drivers. The drivers drove for two weeks without any feedback from the instruments followed by two weeks with feedback (Dinges, Maislin et al. 2006). Although there was no change in the amount of sleep obtained between the two conditions, drivers were significantly less drowsy when driving at night in the feedback phase than in the non-feedback phase. Interestingly, performance on an intermittent PVT was worse while drivers were receiving feedback, suggesting that technologies cost the driver in terms of response effort.

Data collected by driver monitoring instruments has the potential to inform those wishing to manage fatigue about when and where fatigue actually develops among employees, and what the effects of this are in the field. However, in many cases the organisation will simply not have the resource to analyse the data emitted from the a battery of driver monitoring instruments (Dingus, Neale et al. 2006).

A useful review of state-of-the-art technologies and instruments in this area is given by Wilschut et al. (2009) as part of the ERANET 15 project.

4.5 Stimulating the fatigued driver

The use of stimulants, hypnotics or other interventions (e.g. blue light) to prevent drowsiness while driving can also be considered by organisations. These measures are not considered in detail in this report because we believe that a guiding principle for organisations managing fatigue should be that prevention of fatigue is far better (and easier) than cure.

4.6 Developing an appropriate organisational context for fatigue management

So far we have outlined the tools and technologies that could be exploited in an attempt by a transport company to manage fatigue in its drivers. Other tools, which may be no less important, include those which pave the way for successful implementation of interventions by ensuring that organisational conditions are receptive at all levels of the company.

Perhaps the most important tool in this regard is one which describes how the elements of an FMP can be selected according to the organisation's nature and requirements. <u>However, as far as we are aware, no systematic tool is available with which to do this.</u>

Several on-line tools are, however, available to help document management intent and commitment in the form of fatigue policy. Policy will normally need to outline processes for monitoring fatigue in drivers, including collecting and analysing (non-punitively) self-generated reports; and processes for investigating and recording incidents that may be attributable in whole or part to fatigue. The policies should be developed in consultation and ensure protection of data used and managed.

Generic tools can be used to perform a needs analysis, in which fatigue causes and outcomes are measured over a set period in order to highlight the requirements of a management intervention. Paper or internet surveys can be used to assess driver habits, sleep debt or fatigue indices, and diaries and logs can be used to monitor driver sleep, driving hours and break times (Gertler, Popkin et al. 2002) (Friswell and Williamson 2005) Driver and manager surveys, interviews and focus groups can be used to map the basis of the change needed, and inform pre-/post-intervention comparisons

Recruitment and selection tools (psychometric tests, behaviourally-anchored competency interviews) can be used to select those drivers more suited to shiftwork, for example, or drivers with more experience who are less susceptible to fatigue (Trutschel, Sirois et al. 2009).

A sleep contract[4], although probably viewed by many as an attempt to state a formal obligation of the employee to get enough rest prior to work, has recently been usefully reframed to stress that the contract aims to encourage open reporting by employees of fatigue, the management of which is then the dual responsibility of management and employees (Holmes, Baker et al. 2006). A sleep contract

[4] For an explanation see Chapter 7.

includes a framework for reacting to fatigue, negotiated on consultation with employees.

Published measures of safety climate and culture, trust, organisational commitment, wellbeing and job design may also be relevant to organisations considering FMP implementation (Mullarkey, Wall et al. 1999).

4.7 Summary

Tools and technologies are available that can assist in the management of fatigue by transport companies. They can be used to implement and run the programme, educate employees about fatigue, to analyse and develop schedules and rosters, to measure fitness-for-duty, and to measure and assist driver performance.

Implementation of a fatigue management programme requires careful consideration of the nature of the organisation to be assisted. On-line tools are available for developing fatigue policy, and tools for carrying out a programme needs analysis are available in the literature. The latter generate useful baseline data on fatigue levels, fatigue-related behaviour and performance, which can be used in subsequent information campaigns and as the first measure in a programme evaluation. Tools for developing competencies for use in selection and recruitment are also available. However, no tool is available that helps FMP elements to be selected according to the particular contingencies of the organisation.

Modular training packages are available from authorities or safety associations that are designed to increase driver knowledge and awareness of fatigue, outline coping strategies, or explain how diet and health is connected to fatigue. Materials are also available that convey the dramatic effects that fatigue can have on driving. For managers the focus may be on giving evidence-based knowledge on fatigue and driving, and explaining how to account for fatigue in schedules and rosters. Training materials can also be targeted at other stakeholders, such as families of drivers, customers or politicians.

Modular training packages should be adapted to suit the particular organisation in which they are used. Preferably, training should be designed based on a needs analysis for that organisation, outlining the competencies that need to be trained. In this sense, needs analysis tools may be at least as important as the training materials themselves.

The effects of training packages on actual behaviour, performance or operational measures are not clear. One study suggests that directed group discussions may be a more inexpensive alternative, and at least as effective.

Recommendations on how to account for fatigue in scheduling are available in the literature, but these may be confusing for managers. Scheduling tools are therefore useful ways to implement evidence-based knowledge on fatigue in ways that managers can understand. Each of these tools is based on one of several biomathematical models described in the literature. These models predict future fatigue risk for a given schedule or actual driver sleep history. The models account for sleep history, circadian influences and in some cases sleep intertia. Problems with scheduling tools are: manager over-reliance on their predictions; that they do not account for considerable inter- and intra-individual variations in fatigue proneness; and that they only consider a few of the many influences on fatigue. Despite this, practicality and functionality has been demonstrated.

Tests are now available that can output indicators of driver fitness for duty. These include relatively well-established PVTs – which can be performed in the cabin on palm-top computers – and bench-top instruments for pupil analysis. More field studies are needed to assess the validity of these indicators.

Although still in development, technology that can measure and assist driver performance is becoming an increasingly realistic option, especially for large long-haul companies. Options include eye-closure monitors to warn a driver that he is fatigued; and devices that can help drivers with the physical effort of driving in high winds. The hope is that such devices will eventually be integrated in an adaptively automated driver support system.

5 Need for Fatigue Management Programmes

It is increasingly recognised that the operations and employees of transport organisations could benefit from attempts to actively manage fatigue, and more and more Fatigue Management Programmes (FMPs) are being implemented. However, we do not yet know whether such programmes are effective.

To provide a background for the qualitative evaluation of 61 FMPs in Chapter 7, the present chapter defines an FMP, describes how FMPs have developed and describes some common elements, while Chapter 6 presents a consideration of how FMPs can best be evaluated. The main focus throughout both chapters is the management of fatigue in the road sector. However, in outlining and assessing FMPs we are keen to learn from experience in fatigue management in the rail, aviation and marine sectors, where fatigue is also responsible for a substantial share of accidents (Boivin 2000)[5].

5.1 Definition of a Fatigue Management Programme

We consider an FMP to be *a concerted effort to manage fatigue in a transport setting using at least one organised intervention*. In more detailed terms it is any attempt by an organisation to reduce the severity of one or more fatigue outcomes that can reduce the performance or wellbeing of its employees – and hence operational performance of the organisation – by managing one or more of the antecedents of fatigue.

According to our definition, an FMP can range from something as simple as a one-off fatigue training programme to something as complex as an ongoing, adaptive, integrated and dynamic process with continuous input from measures of fatigue causes and outcomes. The definition is broad because we want to learn both about the effect of isolated measures used to manage fatigue and the effect and composition of the exciting new wave of evidence-based, dynamic and systemic approaches. Where the latter aim to reduce fatigue risk “to as low as reasonably practicable”, they are denoted Fatigue Risk Management Systems

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[5] As in the road sector, occupational drivers in the rail industry are faced by challenging schedules (Moore-Ede, 1996; Boivin, 2000). They have excessive working hours, often work at night, are subject to cognitive underload, sleep disorders, and poor sleeping facilities at terminals (Gertler & Raslaer, 2009). The aviation industry also views fatigue as a growing problem, with the lack of sleep on multi-leg trips developing such that performance gradually worsens (Caldwell, Mallis, et al., 2009). In this sector there is also the prospect of ultra-long range operations, in which duty days will increase to 20 h and over, beyond any of the current duty time regulations. How fatigue is managed here could be especially informative. In the maritime industry periods without sleep lasting longer than 24 h are common, and the need to address fatigue as a risk is increasingly recognised by regulators (Rhodes & Gil, 2002). There are therefore several reasons to believe that fatigue management experience across modes is relevant.

(FRMS) (Stewart, Holmes et al. 2006; ALPA 2008). FRMS are often deployed as part of an organisation's larger safety management system (SMS), in which case fatigue is considered as one risk factor alongside and in interaction with other risk factors.

5.2 Need for Fatigue Management Programmes

A survey designed to give a snapshot of fatigue management by US road transport companies in 2001 showed that only about half of them had any formal fatigue management policy (Feyer, Williamson et al. 2001). What policy there was usually just outlined hours of work regulations, and was often communicated to the drivers only verbally or not at all. Many smaller companies (those with less than 50 trucks) did not even have a policy, only one in four of the larger companies ran any sort of fatigue training, and no companies attempted to minimise night driving.

Out of over 80 trucking companies in Western Australia, only 17 per cent had any sort of fatigue management policy or plan and practices were often found to be 'inconsistent with the management of fatigue' (Arnold and Hartley 2001). Worse still, 69 per cent of companies either had no limits for driving hours or hours in excess of 14 h. Of those companies limiting driving hours, one third did not communicate their policies to their drivers, and 80 per cent of companies had not provided drivers with any fatigue management training.

More recently, authors contend that there is limited knowledge of circadian principles in transport organisations, and they do not have the skills to produce rosters that account for systems of factors that cause of fatigue (McColgan and Nash 2009).

One Australian survey found that driver knowledge was more in line with current knowledge on fatigue than manager knowledge, something which highlights the importance of management education as an early and vital part of any successful FMP (Feyer, Williamson et al. 2001). Other authors report signs that managers want to know more about fatigue but are unaware of the current knowledge (Rogers 1998).

Given that fatigue is recognised as the most important safety issue affecting truck drivers, this is a picture that needs to change (Arboleda, Morrow et al. 2003). There is reason to believe that the operations of organisations would also benefit from such a change. Prescriptive legislation has several limitations, is inflexible and cannot account for the way fatigue influences vary between organisations, teams and individuals (Smiley 1998) (see Chapter 3). The reality for many road transport organisations is that delivery times at outlets is often non-negotiable, which means hours of service legislations are impractical. This is especially the case where distances are large (Nolan 2005), or where the goods delivered have a limited lifetime. For perishable goods, for instance, scheduling needs to be reactive not only to seasonal demands but to daily price fluctuations, which lead to varying requirements of customers who act in fiercely competitive environments.

Given the above problems, organisational-level interventions that educate drivers and managers and allow for flexible but safe scheduling are promising ways forward. Management of fatigue at the organisational level has the potential to allow the monitoring and accounting for factors such as trip preparation, quality and quantity of rest, cumulative effects, circadian rhythms, individual differences, unforeseen factors and day-to-day variations (Moore 1998). An integrated programme that addresses the requirements of different groups in an operation increases the chance that fatigue countermeasures will succeed (McCallum, Sanquist et al. 2003). Once established, an FMP would give a foundation for organisational commitment, cooperation and knowledge. Finally, theories suggest that employees of an organisation empowered and motivated to manage fatigue in order to gain operational, performance and wellbeing benefits, will do so in a very effective manner (Clegg 2000).

Recent years have therefore seen some countries attempt a shift in emphasis from prescriptive hours of work legislation towards management of fatigue risks at the organisational level. This has been the direct result of several state, national or international governing bodies seeing organisational-level management as a better way to protect both the public and their employees from the hazardous effects of fatigue on driving (Gander, Hartley et al. 2010). The shift makes it increasingly important to understand a) which measures and b) which organisational factors influence effective fatigue risk management (Gander, Hartley et al. 2010).

Although the active management of fatigue may be appealing to organisations, there will at the same time be several reasons why those same organisations will not want to implement an FMP. The costs of establishment of such a programme in terms of initial staff consultations and policy drafting are no doubt considerable for any organisation. The need to introduce technology, extra documentation, auditing systems and a change in organisational culture may seem too difficult to surmount, especially for smaller transport companies, a fact which has led some authors to claim that financial support should be given by regulatory bodies to ensure no commercial disadvantage for smaller operations (Neville 2000). Another challenge for FMPs is that fatigue must be managed against safe levels of predicted alertness, but it is not clear what those levels should be. In addition, the ultimate proof in terms of FMP effectiveness will be the number of fatigue-related crashes, but (i) this will be hard to prove at the organisational level; and (ii) attribution of a crash to fatigue is problematic. Finally, there is a danger that FMPs will be viewed as attempts to subvert the hours of work legislation, by employee groups to gain better pay and time off, or by employers to maximise productivity using the increased flexibility afforded by FMPs to better align driving hours with operational demands (Dawson and McCulloch 2005).

5.3 Formal fatigue management by transport organisations: a growing trend

Before the 1990s most attempts at managing fatigue at the organisational level were limited either to driving hours prescription or fatigue education programmes. The latter often listed simple countermeasures, many based on little empirical evidence, and placed the onus for countering fatigue solely on the driver (Haworth and Herffernan 1989).

Formal FMPs are considered to have begun in 1994 when the first recognised comprehensive scheme was developed and piloted by Queensland Transport in

Australia (Knipling 1998). Queensland Transport saw fatigue as a growing safety risk, and one which the existing traditional hours of work legislation was unable to address (Feyer, Williamson et al. 2001; Nolan 2005). They therefore devoted considerable resource to changing the way fatigue is managed by its transport companies. Participating fleets were granted relief from prescriptive hours of service legislation in return for implementing a comprehensive programme to prevent fatigue through informed scheduling, driver and manager training, and driver screening. For Queensland Transport, the FMP was "*a performance-based approach to managing fatigue that places the onus on the operator to take responsibility for and manage the fatigue of their drivers*" (Mahon 1998). Thus for the first time, the focus of responsibility for fatigue risk, and with it the motivation to control fatigue risk, was shifted from the government to individual organisations. Several commentators saw this formal FMP approach as an improvement on higher level prescriptive legislation because it was designed to identify and tackle *all* factors that cause and increase the risk of fatigue, not just hours of service.

Shortly following this initiative, Western Australia, a non-legislative state, proposed a Code of Practice for its road transport companies that incorporated many of the fatigue management elements of Queensland's FMP (Poore and Hartley 1998). Around the same time the Canadian Trucking Association proposed an FMP pilot study for the province of Alberta, laying the groundwork for the North American Fatigue Pilot study involving Canada and the US (Knipling 1998). The US also closely followed up with its own National Research Council policy study.

In the late 1990s the airline industry, particularly in Canada, UK and the USA, began to map the problem of fatigue, and accept that traditional prescriptive approaches to fatigue management were unlikely to be the best way to improve safety (Booth-Bourdeau, Marcil et al. 2005). A notable effort also began around this time in the maritime industry in the form of the US Coastguard's Crew Endurance Management Systems (Emond, Stevens et al. 2005) and the International Maritime Organisation's guidelines on fatigue management (IMO 2001). Also in the late 1990s research literature began to heavily criticise prescriptive regulation, with one article stating that despite a "*vast body of evidence*", there was still "*no attention being paid to the impact of time of day in regulatory frameworks*" (Feyer and Williamson 2000).

In 2000 an Australian parliamentary inquiry into fatigue in transport determined that fatigue should be managed in the same way as more traditional workplace hazards such as chemicals or manual handling (Queensland:Government 2010). In the same year the New Zealand road transport FMP trial began, eventually to be discontinued due to new regulations and lack of operator buy-in (Jackson, Holmes et al. 2009).

In 2003 the Human Factors Coordinating Committee at the US Department of Transportation issued its Commercial Transport Operator Fatigue Management Reference as part of a series of tools aimed at informing and promoting fatigue management practices in US transport organisations (McCallum, Sanquist et al. 2003). This was not, however, accompanied by any regulatory opt-outs based on FMPs. Instead, the government introduced new hours of service regulations to account for research into circadian rhythms (Hanowski, Hickman et al. 2009).

These proved to be unpopular with drivers, who preferred the greater flexibility of the previous rules. The 2003 rules were struck out by a Federal Court Ruling in 2007. The North American Fatigue Pilot FMP project (see above) has been quoted by some as laying the groundwork for a more fundamental change in the US, although this has yet to emerge (Bagdanov 2005). Professionals in the field of Health and Employee Assistance in the US recognise a failure to account for fatigue, and recommendations are made that FMPs be incorporated as part of general health management (Holland and Leutzinger 2003).

More recent development of formal FMP approaches in the road sector is particularly influenced by rapid progress in the air sector. New Zealand's air authorities initiated an alternative compliance scheme in 1995, and Australia's Civil Aviation Safety Authority followed suit in 2001. In both cases FMP use has been encouraged by the opportunity to work outside flight time limits. In 2005 easyJet, through documentation of its FRMS approach, became the first UK airline company to be granted exemption from the Civil Aviation Authority's Flight Time Limitations (Stewart, Holmes et al. 2006). More recently, the International Civil Aviation Organisation (ICAO) reviewed proposals to amend its Standards and Recommended Practices to allow for fatigue risk management as a regulatory alternative to prescriptive limits for addressing fatigue (Graeber 2009).

In 2008 the UK Department for Transport commissioned a world-wide study to explore fatigue management experiences in the transportation industry[6]. Plans are also afoot to trial FRMS in a sample of road transport operators in the UK (Jackson, Holmes et al. 2009). The current UK approach is to enforce European and national hours of work legislation and to give advice to organisations on carrying out a fatigue risk assessment under existing health and safety legislation. A checklist of factors to consider in a fatigue risk assessment has recently been recommended by the UK's Health and Safety Executive (Gall 2006).

Recognising the difficulties of political disagreement within organisations when implementing FMPs in Australia, influential arguments have also been made there to include FMPs as part of a risk assessment approach required under Occupational, Health and Safety legislation (Dawson and McCulloch 2005). An essential part of this approach is a change in focus from prescription of hours of work limits to prescription of fatigue *outcome* limits (Neville 2000; Dawson and McCulloch 2005; Moore-Ede 2010). Dawson and McCulloch (2005) claim that an FRMS approach can be shaped by adapting Reason's (1997) "defences in depth" model of risk management. In such a model the provision of adequate sleep opportunity by the organisation and monitoring actual sleep obtained form, respectively, the first two of five layers of defence to be maintained against fatigue-related accidents[7] (Reason 1997; Moore-Ede, Heitmann et al. 2004; Dawson and McCulloch 2005). This approach has recently been incorporated into Queensland Transport's guide for implementing FMPs (Queensland:Government 2010). Moves to incorporate FMP within a risk management framework are also evident in Western Australia's latest code of practice (Gander, Hartley et al. 2010). Predictions that all airlines will soon be required to incorporate an SMS

[6] These are due to be published in 2010 (Jackson, personal communication).

[7] Level 3 is monitoring for any fatigue-related behaviours; level 4 is monitoring for any fatigue-related errors; and level 5 fatigue-related incidents.

that accounts for fatigue risk also reflect developments managing fatigue as one of many threats to safety (Stewart, Holmes et al. 2010).

Despite these developments, most current policy governing road transport companies in wider Europe aims to delineate approved shift pattern standards and durations, and to check organisational rosters against these standards for any unapproved patterns. Although this approach is now more grounded in evidence than traditional hours of work approaches, it has been criticised as failing to account for individual differences (Dawson and McCulloch 2005).

Another significant recent development, again in Australia, is the national Heavy Vehicle Driver Fatigue reform in 2008 (Gander, Hartley et al. 2010). Under this reform companies can seek accreditation in the National Heavy Vehicle Accreditation Scheme, which allows operators to choose to adopt a basic or advanced FMP. It is a staged approach that allows companies to progress further outside hours of work legislation as they become more adept at managing fatigue (Friswell and Williamson 2005; NTC 2007; Williamson 2008). The knowledge, awareness and compentencies required by management and employees of companies wishing to set up an FMP are detailed, along with other details, in published standards (NTC 2007).

Awareness of FMPs and FRMSs appears to have increased exponentially recently, and several government regulatory bodies and industry associations appear to be considering them (Moore-Ede 2010). In the last two years alone: the European Aviation Safety Agency made FMPs a requirement for airlines with operations in Europe; the American Petroleum Institute issued a management standard describing FMPs as a way to manage risk; and the Federal Rail Safety Act made FMPs mandatory on US railroads (Moore-Ede 2010). FMPs seem to be evolving more and more as part of organisation's obligatory monitoring and control of workplace risks under health and safety law (Gander, Hartley et al. 2010). A key to rapid progress in recommending or passing legislation on implementing FMPs at the regulatory level has been the adoption at national level of fatigue as a hazard to be managed under traditional Occupational Safety and Health law (Gander, Hartley et al. 2010). In addition to avoiding cost of incidents and reducing worker absence and turnover, an increasing reason for organisations to implement an FMP is to provide proof of the company's due diligence in meeting this legislation (Enform 2007).

Today only a handful of jurisdictions currently accept FMPs directly as an integral part of safety regulation, and most relate to the governance of aviation (Dawson, Noy et al. 2010).

5.4 Summary

Out of an increasing recognition that modern fatigue issues faced by occupational drivers cannot be tackled by hours of work legislation, there have been growing calls for fatigue management at the organisational level. Accordingly, regulatory authorities are attempting to encourage more transport companies to manage the extent to which their drivers are exposed to fatigue.

Several lines of evidence suggest that organisational-level management of fatigue would be effective. In some organisations managers have had a poor understanding of fatigue, and underrated fatigue problems faced by their organisation. Charging these managers with responsibility for fatigue would increase their awareness and understanding, and lead to improved conditions for their drivers. Drivers and managers who believe that FMPs will bring operational, performance and wellbeing benefits, will be highly motivated to manage fatigue and may do so in an effective manner.

Drawbacks of FMPs are that they are expensive in the short term. Small companies are likely to be daunted by the staff consultation, policy drafting, technology purchase, documentation, auditing and change in organisational culture that FMP implementation may demand. A challenge for regulatory authorities is therefore how they can encourage companies to take on more responsibility for fatigue management. Recent evidence suggests that attempts are being made to persuade companies that they need to manage fatigue like any other risk, within an effective safety management system. This circumvents the need for new legislation on fatigue management.

6 How should Fatigue Management Programmes be evaluated?

An independent evaluation of the overall effect of any FMP is important. It is needed so that an organisation can credibly inform its employees, regulators and other stakeholders either that a programme has been effective or that it needs to be developed further to make it more effective.

Such an evaluation might be considered an obligation under health and safety law, because without it an organisation cannot possibly know whether fatigue risks have been controlled so far as reasonably practicable. The longer term costs of such failure may be greater to the organisation than the short term costs of the evaluation itself.

FMP evaluation is also needed to generate a body of knowledge concerning FMP effectiveness, so that governments and regulators can compare FMPs with other main approaches to tackle fatigue, such as hours of work legislation.

Despite these needs, many organisations do not carry out an effective, independent evaluation of their attempts to manage fatigue. Progress through reliance on the "cumulations of wise practice" in place of formal evaluation is less costly to the organisation in the short term, is a lot quicker, and does not expose the organisation to the risk of knowing that an intervention has not worked or, worse still, has had negative effects.

To promote evaluation by organizations, consultants and researchers alike, a specific aim of our part of the ERA-NET 15 programme was to document what is needed to enable the quantitative evaluation of FMPs. This chapter is devoted to considering how FMPs might best be evaluated.

To begin with we consider an appropriate experimental design that can be used to evaluate an FMP intervention in an organisation.

6.1 Internal validity

Any valuable evaluation involves at least one formal comparison. Attempts to evaluate by recording a one-off measure of one or more fatigue outcomes following an intervention will therefore be "almost without scientific value" (Campbell and Stanley 1963; Shadish, Cook et al. 2002).

A better alternative is to record a fatigue outcome before and after the FMP intervention. Where "O" is an observation, and "FMP" the beginning of the intervention, a timeline for the evaluation can be described as O-FMP-O (design 1).

Design 1 still does not enable the organisation to conclude even with reasonable certainty that the effect was due to the intervention. This is because fatigue outcomes are influenced by many factors other than the FMP intervention (e.g.

seasonal acitivity and other organisational changes). Another problem with design 1 is it is difficult to know when each O should be taken. For instance, it is desirable that the second measure is taken a relatively long time after the intervention because initial response to an FMP may be different to that after the intervention has bedded down and people are accustomed to the new procedures involved (Friswell and Williamson 2005). There may also be a need to compare pre- and post- measures at times of the year when workload is similar, meaning that the before and after measures need to be separated by at least a year. However, a company will often not want to wait, being eager to inform stakeholders about any initial changes in addition to later ones.

For practical and scientific reasons, design 1 would be improved by analysing the effect of the intervention on a time series of measures before and after the intervention, thus for example: O1-O2-O3-FMP-O4-O5-O6 (design 2).

A substantial effect on a downward or upward trend coinciding with an FMP gives reasonable evidence that the effect is caused by the intervention. The design will also inform about the dynamics of the FMP effects, in order to inform future roll-outs. This design also allows fatigue outcomes to be compared over the course of a roster cycle, before and after the intervention, in order to learn about any particular problems remaining for drivers at certain times of the cycle.

Using design 2 we still would not know for certain whether any changes coinciding with the intervention were due to chance variation in a confounding factor. To reduce the level of doubt we could select drivers from within an organisation at random, and compare the effect of an FMP on their fatigue outcomes with those of a well-matched, randomly selected comparison group, who are not exposed to the programme. The latter group would inform about any changes due to other organisational interventions, or market or seasonal changes (Friswell and Williamson 2005).

In practice, however, operational restrictions often prevent such random assignation of employees within an organisation. Furthermore, even when the intervention is simple (involving for example a training session or schedule alteration) the nature of operations and employee interdependence mean that the comparison group is never completely isolated from the effects of the intervention on the treatment group. An alternative way forward is therefore to compare the effects of an intervention on fatigue outcomes for employees in one organisation or site with those from a comparison organisation or site:

Treatment	O1-O2-O3	FMP	O4-O5-O6	
Comparison	O1-O2-O3		O4-O5-O6	(design 3)

Although the employees are not randomly assigned in design 3, it is the most valuable, practical evaluation solution for organisations who want to roll out an FMP for either a whole section of an organisation or whole organisation.

Where design 3 is used it will be important to ensure that fatigue outcomes for the two groups are similar over time before any intervention, initial consultation or pilot is initiated. If matching of participants is not practical, demographic measures of the employees may be compared to inform about the suitability of the comparison group.

To sum up, in terms of knowing with reasonable certainty whether the intervention made a difference, in most practical situations we would know with most certainty using design 3 or, if this was not possible, design 2. These designs would do well to inform us about whether FMPs have an effect on fatigue outcomes in a particular organisation.

6.2 External validity

It will not, however, be possible from a one-off evaluation of an FMP within a single organisation to say whether the effect would generalise to other organisations. This is because it is impossible to reproduce the conditions of the FMP evaluated. The success of an FMP within a certain organisation will be dependent on abstract factors such as trust, commitment, motivation and safety culture, the particular combination of which will be unique to a single organisation at a certain point in time. To be able to generalise at all will require that many robust FMP evaluations are performed, and that they are reported along with key organisational measures informing on operations, performance, culture and work environment. Only then may we begin to assess the organisational contexts in which certain types of FMP seem to work better.

This assumes, however, that organisations in competitive environments would actively report the effects of FMPs that may be accompanied by performance benefits. It would not be surprising if organisations were reluctant to do this. One way to encourage reporting would be for regulatory bodies to finance independent evaluations.

6.3 Evaluation outcomes

But what outcomes should be observed? What should "O" be in the above designs?

The ultimate fatigue outcome measures of interest are fatigue-related accidents or incidents. The number of fatigue-related accidents occurring per year in an organisation will often be too low for the purposes of evaluation, especially in small organisations (Barling, Kevin Kelloway et al. 2002). In this case the number of incidents or near misses involving drivers may be used as an approximation for accident trends. Incidents may be reported by drivers themselves or observed independently by video observation or other on-road data. Where incidents are self-reported it is important that drivers feel free to report openly any incidents, and that the organisation ensures that fatigue-related incidents are reported reliably by having structured procedures for incident analysis and reporting.

There are four reasons, however, to supplement accidents or incidents with other measures in our evaluation.

First, while it is not possible to state categorically that an accident is due solely to fatigue, it is highly possible that accident numbers will not represent the extent to which an FMP has achieved its aim i.e. to reduce driver fatigue. We must therefore characterise the effects of our FMP using several implicit or explicit measures of fatigue.

Second, there are many other potentially important effects of an FMP. We may wish the FMP to have additional effects, such as improvements in employee wellbeing.

Third, to evolve our approach requires studying how an FMP is working, by taking implicit and explicit measures of driver fatigue and fatigue effects on behaviour and performance.

Fourth, several factors both cause fatigue and are affected by it e.g. health, organisational commitment. To understand an FMP, a time series of measures in several dimensions is implied.

As stated in the last chapter, Dawson & McCulloch (2005) suggest that measures should be structured according to Reason's defences in depth, i.e. that they should measure:

1. Sleep opportunity
2. The amount of sleep drivers actually obtain
3. Subjective ratings of fatigue, objective measures of fatigue-related behaviour (e.g. do drivers stop when fatigued?), fitness for duty tests (vigilance, reaction time tests).
4. Objective measures of driving performance (lane deviations, steering wheel movements), fatigue-related errors and near misses.
5. Fatigue-related incidents and accidents

Where resources are limited, some authors argue that evaluation of fatigue measures and programmes is best centered on performance measures (Williamson, Feyer et al. 2000) (Dawson and McCulloch 2005). The effects of fatigue on performance are what the company is interested in, because it is performance that has direct effects on safety. A battery of PVT performance measures that could be used to evaluate fatigue in drivers while out on the road has been assessed (Williamson, Feyer et al. 2000). Those that showed performance decreases in line with expected decreases due to fatigue were a simple reaction time test, the Mackworth Clock Vigilance test, and a Dual Task test. Each of these tests could be performed by the drivers on the road using a palm-top computer.

Whether health is included as part of an evaluation may depend on whether the organisation attempts to integrate their FMP as part of a broader programme that looks after the employee's physical and psychological wellbeing (Krueger, Belzer et al. 2007).

Many organisations will also want to calculate cost-benefits for the programme.

We now turn to consider measures that can be used to evaluate whether the context of the organisation is suitable or supportive for implementation of the FMP.

6.4 Process evaluation

Organisational context may be evaluated by, for instance, asking whether there was driver support for the training. Were roles and responsibilities for fatigue management clear to all employees? Was management committed to the training?

Was management *perceived* to be committed to the training? Did employees feel empowered to carry out recommended coping strategies? Did they have sufficient self-efficacy (Gander, Hartley et al. 2010)? Alternatively, if the FMP included an attempt to improve schedule management, a measure of how schedules are actually managed over time before and after the intervention would be informative.

In carrying out an FMP the employer takes increased responsibility for the welfare of the employee, who can often perceive the employer's role as shifting from that of a monitoring and enforcing agent to a collaborative, concerned agent. On the other hand, employees may be concerned that employers are exploiting the flexibility of FMP opt-outs to optimise productivity. Thus evaluation of employee trust of management, management trust of employees, organisational commitment or job satisfaction may also be appropriate (Wrzesniewski and Dutton 2001). Related measures here are management and driver awareness and acceptance of FMP policy and interventions, practicability of interventions, employee opinion of effectiveness of changes, measures of employee motivation and empowerment to carry out interventions, and customer opinion of change. Especially important considerations are whether the drivers know why and how attempts are being made to manage fatigue; whether they attend to and comprehend the changes that are being made; and whether they comply with e.g. work-rest scheduling, actigraph or diary use (Newnam, Newton et al. 2009).

Recent trends indicate that it is best that FMPs operate within an SMS where fatigue can be considered alongside other risk factors. This requires a mature safety culture, often characterised by open and proactive reporting; understanding of acceptance of the need for discipline; task variety; and timely and appropriate response to safety information (Reason 1997). Studies in a variety of industrial settings show a link between accident severity and strength of safety culture (Arboleda, Morrow et al. 2003).

6.5 Summary

A robust evaluation is required to learn whether an FMP has been successful and/or inform its further development. Operational limitations will prevent ideal experimental design, but organisations should at least aim to evaluate a time series of measures recorded over two periods, each lasting at least several months, one before and one after the intervention. The before period may also serve to provide information about fatigue issues faced by the organisations for use in driver and manager training and awareness. Ideally, the change between periods should be compared with a corresponding change at similar sites or organisations where there was no intervention.

Many independent evaluations of FMP interventions need to be carried out and reported to inform regulatory authorities, safety associations, politicians and transport organisations about their effects. Alongside the change in outcomes reported, evaluations should report on the culture and context of the organisation involved. Only then will we be able to begin generalising about the effects an FMP is likely to have for a given organisation. Thus additional measures should address any attempted changes in job design or culture attempted as part of the FMP. Where drivers or managers are given increased responsibility for managing fatigue, measuring whether they have the self-belief, information or feedback with which to do so will be important. Perceived management commitment, trust and understanding of roles and responsibilities may also be key measures here.

A competitive organisation has little reason to report the results of FMP evaluation in this way. Regulatory bodies should therefore encourage open reporting, perhaps by financing independent evaluations.

Some authors claim that fatigue outcomes reported by an evaluation should be structured according to different layers of defence against fatigue. The evaluation should in any case seek to report subjective and objective fatigue levels, fatigue-related performance and fatigue-related operational variables. The cost-benefits of the FMP should also be reported.

7 An inventory of Fatigue Management Programmes

This chapter reviews an inventory of 61 FMPs. The aim of this review is:

1. To catalogue and describe common elements of FMPs to date.
2. To identify approaches used to implement FMPs in organisations.
3. To consider how FMPs have been evaluated.

The inventory comprises a wide variety of programme descriptions. We include FMPs that range from an individual measure implemented by a single organisation to a set of comprehensive FMP guidelines issued by regulatory authorities. The aim has been to capture different approaches by learning from a wide range of available descriptions of different FMPs.

To save space in the main body of the report, descriptions of the individual FMPs are given in Appendix A, and they are further summarised in a table in Appendix B. The numbers in square brackets below cross-reference individual FMPs as according to their appearance in Appendix A.

7.1 Description of the inventory

Most of the 61 FMPs in the inventory come from USA (26 FMPs) or Australia (15 FMPs). The remainder is from Canada, UK, New Zealand, France, Germany and Sweden. Six are multinational FMPs.

The inventory reflects our focus on road transport company FMPs, and our wish to learn from other sectors, particularly aviation. Thirty-two of the FMPs are described for the road sector, 14 for aviation, six for rail and seven for the maritime sector. The remaining three per cent cover multiple transport modes.

Just under a half of the FMPs are pilot or demonstration projects carried out by regulatory bodies, safety associations, research institutes or universities. A similar share are descriptions or evaluations of manuals, “toolboxes”, codes of practice, standards, or guidelines for organisations issued mostly by regulatory bodies. Sixty-five per cent of the FMPs in the inventory were implemented in at least one organisation.

7.2 FMP elements

7.2.1 Training

Training is the most popular FMP component. Eighty-three per cent of the FMPs in our inventory describe the education of drivers or pilots about fatigue. Most training programmes are one-off sessions lasting from a couple of hours to two days [2, 9].

Without exception, guidelines issued by regulatory authorities detail the need for training to raise knowledge and awareness of fatigue, improve attitudes towards fatigue, and convey ways to identify and tackle fatigue. The training always targets drivers or pilots, but often managers as well. Managers are often trained in separate sessions. Managers are trained to increase their shared understanding with drivers, to make sure that they are aligned and informed about any upcoming changes, and to increase the chance that they will contribute to positive policy developments in the organisations. Some FMPs also use training to target driver families and other stakeholders (e.g. customers, politicians) [19, 20].

The train-the-trainer approach is often used as an efficient way to increase knowledge of fatigue causes and coping strategies among a large number of drivers, and ensure that managers thoroughly understand the issues [2, 9, 13, 19, 36, 53]. Of the FMPs describing a training element, 13 per cent exploited the train-the-trainer strategy. The trainers trained were managers, health and safety officers or driver representatives. One problem reported with train-the-trainer programmes is that it may be hard for the trainers to understand the subject material [19].

Some companies (e.g. easyJet) employ on-line training, though there are no reports of how effective this training is for increasing knowledge and awareness about fatigue.

The inventory contains examples of robust training intervention evaluations. For example, to measure the effect of training for BP Oil drivers, attitudes to training, subsequent intentions to behave, subjective fatigue, and knowledge before and after the intervention were evaluated independently. Surveys were also used to find out whether the behaviours recommended during training were consequently used by drivers [9]. Post-intervention measures were taken up to a month after training, followed up by a longer time point of several months up to two years. Encouragingly, decreases in subjective fatigue and increases in knowledge were demonstrated. SAFE-T’s Alertness Management Training is another example of training shown to improve driver knowledge of fatigue and improve attitudes [22].

The content of training can vary, but usually teaches about:

- the risks of fatigue to the driver;
- the causes of fatigue, including sleep and circadian influences; and
- effective ways to tackle fatigue.

Several programmes couple training to increase awareness and knowledge about fatigue with improved scheduling [40, 41, 42].

In addition to raising awareness about the dangers of fatigue, Greyhound Bus emphasise to their employees the importance of nutrition and how off-duty activities can affect fatigue at work [40].The Federal Motor Carrier Safety Association of the USA also offers a module stressing wellbeing and health as integral to tackling fatigue [53].

Several of the training programmes are based on pre-prepared modules such as the evidence-based NASA Fatigue Countermeasure Programme or the American Trucking Foundation’s Train-the-Trainer programme [9, 13, 36]. Such modules appear to be based on research evidence, but are not tailored to the needs of the individual drivers or even to the individual transport company.

There is one example of a modular training approach that can be tailored to the individuals being trained [49]. This training is based on a transactional model of driver stress, and was used in an intervention on an Australian coach company. A driver survey was used to develop interactive training exercises in which drivers make judgments about how they would personally react in different scenarios in which they are fatigued. Drivers are then given personal feedback about their coping style and asked to rate the effectiveness of their style relative to others described. The aim of the programme was to make drivers think through strengths and weaknesses of their own fatigue management strategies, and to offer more effective alternatives. An independent evaluation of the intervention showed that post-training self-efficacy and favourable behavioural intentions had both increased, although no behavioural or operational measures were reported [49].

One idea to encourage the transfer of training advice is through the use of trip-specific advice cards. Use of these by British Airways was valued even by experienced crew members [27].

There are few reports that training is based on a training needs analysis, in which the behaviours required for a driver to avoid driving while fatigued are identified and described, and used to design a competency-based training programme (Warr 2002). Only three FMPs in our inventory explicitly used competency based training [17, 45, 55].

7.2.2 Scheduling / rostering

Another common element of the FMPs in our inventory is the accounting for fatigue in scheduling and rostering. Eighty per cent of the FMPs we describe attempt to do this. Almost all guidelines issued by regulatory authorities detail the need for scheduling to account for fatigue causes.

It is often stated as an advantage that FMPs afford flexibility in scheduling, allowing a shift in focus from limiting driving hours driven daily to arranging shift cycle hours to allow the driver the best chance for recuperation over that cycle. To test whether this flexibility could lead to one-off days with dangerously long driving hours, prescribed driving hours (limited to 14 h in a 24 h period) were compared to the maximum allowed under an FMP in Australia (limited to 16 h in a 24 h period) using drivers from three road transport companies [31]. Based on fatigue-related performance measurements (reaction time and vigilance tasks) it was found that driving up to 16 h was not detrimental to performance, as long as the driver was sufficiently rested beforehand. In other words, the longer driving sessions allowed by FMPs are not necessarily dangerous as long as they are balanced by sufficient rest periods.

There are several indications that accounting for fatigue in scheduling leads to positive changes. For example, a schedule change carried out in a shipping organisation aiming to increase sleep opportunity in exchange for extended working periods was positively received by the crew, with a decrease in the number of near miss incidents [34].

In another example, software was used to analyse and develop a schedule used in a company with 500 trucks [23]. Over the year the intervention was carried out, the accident rate was reported to have fallen by 55 per cent. Another attempt to better account for scheduling of engine drivers resulted in reduced subjective ratings of fatigue, but no change in fatigue-related performance [28]. A further attempt to adjust schedules based on software-generated fatigue risk scores resulted in an increase in sleep opportunity [25]. The software used was the Fatigue Audit InterDyne (FAID) software, which appears to be relatively popular. The use of FAID to improve schedules is recommended by Transport Canada, both in its FMP for Canadian Marine Pilots and in its Toolbox for aviator personnel; FAID is also used in RailCorp's FMP [41, 42].

One problem with the use of fatigue risk scores generated by software programmes arises from the need to define risk limits for a schedule [25]. In companies with a prescriptive culture, these limits may simply replace hours of sleep regulation limits. In other words, a pro-active, flexible and informed approach to fatigue management may not occur if scheduling software is the only element in an FMP, and there may therefore be no benefits over traditional approaches to fatigue management.

Continental Airlines' FMP is an example of how scheduling software can be combined with other programme elements to form a central component in a fatigue risk management approach centered on scheduling improvements [37]. Data is collected from surveys, actigraphs and diaries, and used alongside predictive software to inform continuous evolvement of schedules and rosters.

7.2.3 Sleep disorders

Forty-one percent of FMPs attempt to screen and address sleep disorders that may lead to increased fatigue during transport operations, according to our inventory. Medical screening is carried out by trained personnel – a company doctor, clinician or a visiting doctor – to identify and treat relevant drivers. The treatment itself can include education and clinical components. (Processes for the evaluation and effective treatment of sleep apnea are well documented [44].) Medical screening can be part of a company check-up, or occur as a follow-up to a one-off site visit [16] or survey following training session about sleep disorders [15, 19].

Education about sleep disorders to raise driver and manager awareness is often included as part of an FMP, and some programmes are strongly centered on identification and non-punitive treatment of sleep disorders [14, 15, 19, 44]. The data that has been gathered by these FMPs suggests that this is an important element of an FMP. For instance, a project by Worksafe Victoria and the Transport Accident Commission in Australia found that out of 12,000 workers given confidential health screening, almost half were referred to their GP, and 24 per cent found to have a high risk for sleep apnea. An evaluation of the programme reported a significant decrease in lost time injuries. The North American FMP found that drivers slept longer and more effectively after the intervention, both according to self-reports and actigraph data [19]. Scores on a psychomotor task also improved for severely fatigued drivers. However, other than these results it is hard to find reports of the effect of such programmes on fatigue outcomes.

One problem with the treatment of sleep apnea is driver adherence to the treatment, although it is possible to monitor and record adherence rates. Addressing sleep disorders also raises an ethical dilemma for FMPs i.e. should drivers continue to drive after being diagnosed with apnea? One study also finds that insurers are reluctant to insure drivers who must declare problems with apnea [19].

7.2.4 Feedback and advice

Drivers were given personal feedback or advice on their own fatigue in about one in five of the programmes in our inventory.

In one report, driver awareness of their own fatigue risk score was used as a basis for subsequent management by the driver of their own fatigue. Drivers were empowered to adjust their own rest hours as part of the intervention, and coached on how to reduce fatigue scores. The intervention appeared promising, with fatigue risk scores decreasing in line with both driver turnover and accident and injury rates [23].

Actigraph feedback of sleep history has also been used with train drivers. In addition to sleep data, the drivers were able to discuss ways to change their habits. An independent pre-/post-intervention evaluation of actigraph feedback suffered from lack of power so the effects of this intervention were not clear [28c].

Use of actigraphs to give feedback to employees about their own fatigue has been used by drivers in the Swedish army, with anecdotal evidence that the effects were positive [5]. The US army has also described a programme in which drivers' own fatigue levels are fed back to them and used to predict alertness levels in the near future to inform operations, although effects are not reported [7].

Some approaches encourage employees to proactively seek advice on how to manage their fatigue, through helplines [39] or Employee Assistance Programmes [42].

7.2.5 Sleep contract

A sleep contract contains standards on how much sleep an employee must contain prior to work, and states that it is the employee's responsibility to inform management when these standards are breached, or when they experience fatigue. In exchange, management guarantees that no sanctions will be taken and an effective management system will be put in place to respond to reported problems.

Only three of the FMPs in our inventory appear to employ sleep contracts. An interstate road company in Australia as part of a programme of measures, for which reduction in fatigue-related incidents was reported [43]. Sleep contracts are recommended by the Energy Institute's guidance for fatigue management, which are in turn recommended by the HSE in the UK [54].

Some difficulties with operationalising the terms of sleep contracts (e.g. how tired is too tired?) and lack of employee belief that a management system will be triggered by reporting fatigue are reported [43].

7.2.6 Work environment

Some FMPs attempt to tackle the extent to which sleeping facilities or depots promote rest [12, 20]. Improved sleeping facilities in one case is accompanied by empowering drivers to take naps [28]. Western Australia recently issued guidelines on how a company can draw up napping policy [29]. A controlled pilot study on in-flight napping in air crews found that alertness was enhanced by napping towards the end of a flight [30].

7.2.7 Structured learning from fatigue incidents

BP Oil attempt to categorise and structure the information collected on the involvement of fatigue in company accidents using a method developed by the National Transportation Safety Board [9]. A two-page form devoted to describing fatigue factors surrounding incidents and accidents is given to investigators.

7.2.8 FMP elements recommended by published guidelines

Most FMPs appear to combine several of the above elements together when tackling fatigue. Indeed, most guidelines and standards describe that fatigue needs to be tackled on several fronts.

According to Queensland Transport an effective FMP gives drivers the flexibility to reschedule driving, and includes the following measures:

- scheduling and rostering (to account for fatigue, recovery and individual preferences);
- accurate records of time worked;
- fitness for duty measurement;
- health screening and treatment;
- open lines of communication between drivers and management (‘just culture’); and
- training and education of drivers and managers.

An FMP policy must be in place, and procedures for non-compliance, record keeping and internal auditing are also part of the programme.

More recently, Basic and Advanced FMPs have been described by the Australian Transport Council. For Advanced FMP opt-outs, a customised and auditible SMS must be demonstrated, with controls specific to the fatigue risks of the company’s operations [55].

In Western Australia it is recommended that the following be attended to as part of an FMP:

- scheduling;
- fitness for duty;
- health management;
- workplace conditions;
- training;
- policy;
- procedures (including those detailing management responsibilities and non-compliance); and
- record-keeping.

The Canadian rail project CANALERT stresses the improvement of schedule predictability, sleeping environment, introduction of a napping policy, and lifestyle training for drivers and families [20].

Recently the US Department of Transportation’s Operator Fatigue Management Programme published a Fatigue Management Reference Guide [3] detailing fatigue-related operational risk factors. It states that the components of a good FMP are:

- policy-driven organisational commitment;
- employee-employer partnerships;
- education and training;
- employee health screening and programme; and
- evaluation and refinement against objectives.

As for most guidelines, however, it is not known how many organisations have implemented this advice.

The Transportation Research Board in the USA has published a Toolbox for Transit Operator Fatigue [32]. A collection of tools and strategies are presented that can be selected and tailored according to the cultural and operational characteristics of the transport company. Most tools are accompanied by training. The Toolbox addresses the following themes:

- managing personal habits and behaviours;
- fitness for duty;
- managing service delivery;
- analysing and creating run schedules;
- temporary personnel;
- designing facilities and equipment;
- recruiting and hiring new operators; and
- investigating accidents.

There is no known evaluation by an organisation that has used the Toolbox.

Another public domain “toolbox” is described by the Civil Aviation Directorate and Transport Canada [45]. There are three main elements:

- policy development;
- training and education for all employees; and
- audit and management systems for determining and controlling fatigue levels in the company.

The Federal Motor Carrier Safety Administration’s programme in the US [53] also has multiple elements, including:

- health and wellbeing training and awareness for employees and families;
- health screening and non-punitive treatment; and
- scheduling development.

The Crew Endurance Management System developed by the US Coastguard stresses three main elements:

- the improvement of knowledge around fatigue;
- working (and sleeping) environment; and
- scheduling for optimal alertness.

It also states that a structured risk assessment process should be carried out evaluating 15 risk factors in the following five categories:

- sleep;
- schedule;
- physical stressors;
- environmental stressors; and

- personal stressors.

The use of the System by a barge company resulted in a new schedule on which crew were over twice as likely to get over 5 h sleep [35]. Baseline measures for evaluation of a demonstration project have also been made [47].

Finally, a multi-element FMP was rolled out across six sites by BP Oil. It included developing rostering guidelines, train-the-trainer education on fatigue awareness and countermeasures, a company napping policy, napping kit, sleep disorder monitoring and treatment, and a new database to enable the role of fatigue in accidents to be analysed to inform the programme in the future [9].

7.2.9 Risk management approaches

Thirty-five per cent of the programmes in our inventory used some sort of risk management approach.

Like several other airlines, easyJet describe a FRMS approach within a pre-existing SMS framework [17]. Here the aim is to control risks due to fatigue by considering schedules, other operational influences and personal influences within a system continuously informed by several sources of relevant data such as crew surveys, software-based fatigue predictions and objective measures of sleep.

The Energy Institute's recommendations on fatigue management stress that factors to be considered in a risk assessment of fatigue are:

- shift lengths;
- schedules worked;
- rest periods between shifts;
- nature and demands of job, sleeping patterns of staff;
- working environment;
- travel time before and after shift;
- substance use likely to affect alertness; and
- age.

The bodies responsible for policing the aviation industry are strongly encouraging that fatigue be managed like any other safety risk (Caldwell, Mallis et al. 2009). In the US the Flight Safety Foundation recommends FRMS for envisaged ultra-long-range operations. FRMS are also being used by Transport Canada on aircraft maintenance engineers. The International Civil Aviation Organisation is compiling a report outlining a recommended FRMS, and the Federal Aviation Authority is also exploring ways to implement effective FRMS.

The risk assessment approach is also being increasingly in the transport sector as a way to legislate for fatigue management within existing health and safety law (Queensland:Government 2009).

Shell has managed fatigue through a colour-coded process to facilitate the assessment of fatigue and any subsequent control measures necessary [6]. When an employee assesses that a planned or ongoing journey has three or more points of danger, he or she has to change an aspect of the journey or stop. One of the danger points must then be addressed (changed to green) before the journey can go ahead. For example, if an employee must take a long flight (one orange) and then drive a long way (two orange) on the wrong side of the road (three orange) the person must do something about one of these points of danger, such as breaking up the distance driven.

7.3 Implementation

Regardless of composition, no FMP will be successful unless it is implemented successfully. Implementation has several aims. It seeks to ensure that the FMP is audited and documented in such a way that it meets regulatory requirements. It seeks to ensure that both drivers and managers at all levels in the organisation understand and are engaged by the programme. Furthermore, several organisational prerequisites, such as level of driver autonomy or openness of reporting culture, may need to be in line with different FMP elements.

7.3.1 Encouraging implementation

As we have seen, Queensland Transport was the first regulatory body to offer organisations exemption from hours of service regulation in exchange for demonstration and documentation of an effective FMP [10]. Recently, this has inspired reform on the national level, in which two types of FMP opt-out are offered, depending on the extent to which an organisation can demonstrate to inspectors that it can manage and audit fatigue in its employees [55].

The contrasting approach in the US has been to publish a well-researched set of guidelines or tools for fatigue management, with advice on how they can be implemented. The US Department of Transportation's Operator Fatigue Management Programme [3] gives thorough background knowledge and a tool on how to construct a business case for the intervention. Scheduling software recommended is also accompanied by a training programme leading to certification for users. In addition, trained advisers are identified that could be used as consultants by small organisations.

The UK's Health & Safety Executive stresses the management of fatigue within a risk management framework, and guidelines for fatigue management supplement detailed accounts of how to do a risk assessment [4]. A similar approach is taken by Western Australia [12, 29]. In these cases documentation that practices and procedures are used to effectively manage fatigue are the single most important defence to a charge of negligence under a health and safety acts, and FMPs are seen as important components in a risk management programme. Any FMP should therefore identify the risk factors and measures to handle them.

Part of the Western Australia approach is the description of standards to be met, and control measures to be used when a standard cannot be adhered to [12]. Apart from this it is very much up to the individual organisation what measures are introduced to manage the way their particular employees are affected by fatigue.

Some programmes, such as Worksafe Victoria's health screening programme [16], are implemented across organisations almost entirely by the authority. In contrast, a private consultant can be hired by an organisation to implement a programme [23].

7.3.2 Implementation within organisations

Some larger organisations – especially those in the aviation industry – introduce their own FMP as part of an evolving safety management policy.

For example, easyJet describe a highly integrated approach to fatigue management that appears only to have been possible due to a pre-existing safety management system [17]. Some of the data mined and fed into the FRMS existed before a formal effort to manage fatigue began. The culture described resembles one which has previously been exposed to safety systems, possibly making fatigue workshops, fatigue risk assessments, and surveys easier to implement effectively. Some of the ways fatigue is reported by easyJet (e.g. reports of colleague and own error rates) would not be valid or possible if not for an open reporting culture.

Some evaluations of FMP implementation find that staff may be reluctant to change schedules because of routine [26]. One idea from the Crew Endurance Management System is the identification of staff representatives that may be consulted as champions or coaches of fatigue management to promote change [26, 46]. Another lesson from a successful schedule alteration by two different shipping companies is to give a small demonstration project high visibility to the rest of the organisation, so that they become convinced of the need for change [34, 35].

Several other FMP implementations recognise that resistance to change needs to be tackled, and that one way to do this is to involve all stakeholder groups in any intervention from the outset. We were pleased to find that sixty-one per cent of the FMPs consulted the driver as part of the intervention design. Continental Airways point out the importance of a Fatigue Risk Management Team with representation from all stakeholder disciplines at multiple levels [37]. The team reports to a Safety Review Board, which ensures integration with the organisation's SMS. The CANALERT project also stresses the importance of a cooperative approach, in its case by forming from the outset a partnership of transport organisations, consultants and employee representative organisations, and authorities [20]. Air New Zealand ensure that management and unions work together from the outset, and place particular emphasis on the maintenance of 'just culture' with openness and feedback seen as essential to fatigue management within an SMS framework [38]. Similarly, the US Coastguard's influential Crew Endurance Management System [33] stresses the importance of setting up employee-employer partnerships to develop a plan. Representative of stakeholder groups form a working group, which includes consideration of company mission and policies in forming plans to tackle fatigue.

The Crew Endurance Management System emphasises that an important aspect of schedule redesign is whether those who are affected by the schedule are able to participate. A barge company implementing the Crew Endurance Management System used a highly participative redesign after a 1.5 d workshop to help them analyse and design work schedules and cycles [35]. Positive outcomes of this process included agreement by crew to maximise rest before work and limit alcohol and overeating.

The Crew Endurance Management System's implentation process is iterative as follows:

- set up the Working Group;

- analyse current fatigue status;
- develop endurance plan;
- implement;
- evaluate; and then
- feedback to 2.

Use of the System by AC Barge resulted in anecdotal observations that casual management support is insufficient; that it is important to educate all managers; that clear reasons for change should be made salient to counter resistance to change among employees; and that in-house champions are key [46].

The Transport Research Board's Toolbox [32] has a chapter devoted to organisational prerequisites and FMP implementation. It stresses the importance of a top-down implementation and of organisational change processes. The foundation process comprises:

- securing and maintaining management commitment
- policy and programme development
- communication and training
- managing fatigue and alertness
- monitoring, reviewing and modifying.

Tools are outlined that can be selected for use at each of these stages by the manager or team responsible for implementation (see Elements).

Transport Canada's Toolbox for aviation personnel stresses that clear policy and organisational prerequisites are essential to the success of an FMP [45].

The USA's Flight Safety Foundation recommends the following process can be used to develop risk management policy:

- formalise training
- crew fatigue reporting and feedback;
- set up objective fatigue measures; and
- implement processes and procedures for evaluating and acting on information.

Enform describe a similar implementation process in its recommendations on FMP design to various oil companies [48]. There is somewhat more emphasis, however, on the building the competencies required by drivers and managers through a structured needs analysis and training cycle.

Some FMP implementations are phased, in which the first phase is often a survey to capture operator fatigue states over a defined period, and to consult with operators as to their views on the causes of fatigue. In the development of an educational programme, for instance, Transport Canada followed up a consultation phase to evaluate the effect of different shift patterns on performance [8]. This presumably gave credibility to the education programme that followed. BP Oil used a driver survey to map current fatigue problems and involve drivers in developing rostering guidelines that better account for fatigue [9]. Both drivers employed by BP and contract drivers were trained.

Recent guidelines on FRMS issued by Queensland Government emphasise the importance of underlying culture and senior management commitment. It is also important to identify roles and responsibilities and employ other principles of effective change management [58]

Burlington Northern SantaFe's current FMP involves risk management, job safety analyses, knowledge of safety and operating rules and employee empowerment as part of a safety vision and "closed loop safety process" where employees can stop work if they think it's too risky [60].

Finally, it was notable that the share of FMPs in our inventory basing the program on baseline data was 56 per cent.

7.4 Evaluation

Using the available source material we estimate that forty-four percent of the FMPs in our inventory were evaluated. Fifty-seven per cent of these evaluations were independent. Most evaluations were based on pre- and post-intervention measures. Less than 20 per cent of those evaluations carried out were controlled. In some cases it is stated that the small size of an organisation prevents comparison [e.g. 11]. It most cases it was not possible to determine from the available information the time course of evaluation measures. What is clear is that most evaluations do not attend to the Federal Motor Carrier Safety Association's recommendations that companies establish a FMP for 2-3 years before judging a programme based on predetermined measures of programme effectiveness continuously collected over the period of the programme [53].

Concerning evaluation outcomes, several FMP guidelines recommend that these be multiple and structured according to the five-layered defence model. For example, both Transport Canada's Toolbox and Continental Airlines' FRMS structure evaluation outcomes in this way.

Other guidelines are more explicit [e.g. 32], for example stating the following should be considered:

- operational measures (overtime charges, absenteeism, injuries, safety violations, fatigue-related accidents and incidents)
- objective measures of fatigue and sleep (actual sleep / sleep debt index, fatigue-related performance, physiological measures of fatigue); and
- subjective measures (fatigue self-reports, diaries, logs, qualitative interviews).

Despite such recommendations, most FMP evaluation outcomes appear to be based on training elements. When given, the effects of training interventions are usually reported as learning measures, based on changes in knowledge or awareness of fatigue, although it is sometimes stated that there are plans for more thorough evaluations [e.g. 13]. Out of those FMPs for which some form of evaluation was described in the source material, 90 per cent reported an outcome based on fatigue knowledge or awareness. There is little mention of attempts to link changes in knowledge or attitude to changes in fatigue-related behaviour, performance or operational measures, although an independent evaluation of BP Oil's train-the-trainer programme found that 90 per cent expressed intentions to change behaviour.

For larger organisations it is possible to assess interventions on the basis of accident outcomes. Although drops in accident rates should be reported in the context of previous trends and changes in national accident statistics, this is rarely done [23]. The delicate way in which accident rate changes should be handled have been well described (Elvik, Høye et al. 2009). That fatigue risk scores decrease in line with driver turnover and accident and injury rates [23], however, gives at least some support that a change in accidents is due to changes in fatigue.

Of the FMPs in our inventory, the distribution of evaluation outcomes was follows:

- 22 per cent were evaluated based on accidents, injuries or near misses
- 25 per cent were evaluated based on fatigue-related performance or behaviour
- 23 per cent were evaluated based on operational outcomes such as absenteeism or staff turnover
- 11 per cent were evaluated based on costs

Single evaluations often used multiple measures. Indeed, several examples of quite robust evaluations of FMPs are apparent. An example is the North American FMP, which details qualitative and quantitative elements, and records subjective reports of fatigue, objective measures of sleep (actigraph) and performance (PVT test), and driver reports of near misses [19]. Both perceived and actual programme effects on driver fatigue were recorded, in addition to organisational-level effects.

A first independent evaluation of the Queensland Transport pilot programme did not use any pre-intervention measures, rendering some potentially interesting post-intervention measures of accident rates and driver autonomy next to useless [10] (Mahon 1998). However, there is some interesting anecdotal evidence, suggesting areas in which follow-up research may be worthwhile. For instance, a consultation phase during FMP development resulted in open lines of communication between drivers and management, with the result that drivers were more likely to report truthfully their hours of work. FMPs were in some cases used as a precondition for gaining a contract but sometimes operators were undercut by competitors who did not have an FMP but whose drivers nevertheless drove more than the law allowed.

A later report gives measures for six companies participating in the Queensland FMP scheme, before and five years after implementation of the FMP [10]. These measures are also compared to those taken from control organisations not implementing an FMP. Drivers were more likely to report involvement in scheduling after the intervention and less likely to report job fatigue. Management reported a more proactive role in scheduling and that they liked drivers to be involved. Four of the companies found they operated more efficiently, though revenue changes could not be attributed to the FMP. Companies perceiving the FMP to be a success perceived driver buy-in and an increased understanding between driver and customer as essential. Challenges were changing driver culture, overcoming driver resistance, and administrative burden. Despite this most companies reported that schedules were managed by drivers, and merely given a seal of approval by managers. Implicit, objective measures of fatigue reduction, effects on driver performance, accident or incident rates, and other organisational measures were not reported.

Evaluation of some of the individual tools recommended by regulatory bodies is in some cases ongoing [3], but there are few published evaluations of an organisation's attempt to follow a set of guidelines, standards, codes of practice or recommended tools. Given that most guidelines explicitly set out the need to collect baseline data and a post-intervention as part of an evaluation, this is surprising. It means that despite several authorities issuing impressive guidelines and recommendations comprising elements underpinned by research, we do not know how many organisations subsequently use those guidelines; or whether attempts to use the guidelines are successful. Exceptions to this are the early set of pilot studies by Queensland Transport, and the US Coastguards Crew Endurance Management System [33, 35]. According to the source material there are also plans to evaluate Transport Canada's Toolbox for aviation personnel, based on pre- and post-intervention measures of asbenteeism, error incidents, training knowledge, cost-benefits and subjective opinions of implementation process and toolkit efficacy [45]. According to an abstract based on an upcoming report to the Department of Transport in the UK, vehicles belonging to FMP accredited companies are involved in 50 to 75 per cent fewer crashes, though few details are available at the time of writing (Jackson, Holmes et al. 2009). In addition, following the Civil Aviation Safety Authority's initiation of FMPs in 2001, 90 per cent of managers and 85 per cent of crew members think that FMPs have had a positive impact (Jackson, Holmes et al. 2009).

Only one project [20] involving Canadian rail companies, attempted to evaluate the whole programme in addition to individual elements of the programme. Although a control group was used, the numbers involved were very small (n = 40, divided into three groups) because of an evaluation approach based on physiological measurements. The high inter-individual variation in these measurements meant that significant group differences were not found.

A key comparison, not made by most evaluations, is the sleep opportunity afforded by schedules in relation to actual sleep obtained [51]. This may be a good indicator of lifestyle effects on fatigue, but could also reflect stress at work and individual differences. Another aspect missing from evaluations is that, despite increasing the involvement of drivers in rostering, there are often no attempts to evaluate whether they have the knowledge to do this. Even where this is done, there are no descriptions of formal attempts to measure organisational or other prerequisites to ensure that increased driver autonomy can be used successfully (e.g. trust, information, feedback) [9].

There is also a lack of reports on operational challenges of FMP implementation. For example, there is one report that new rosters suggested by employees were seen by logistics managers as problematic, and it would be interesting to know whether this was a common problem, and if so how it could be prevented [9].

7.5 Summary

A recent review of FMPs carried out for the Department for Transport by Clockwork Research, categorises different FMP measures taken by large aircraft operations approved for alternative compliance in New Zealand (Jackson, Holmes et al. 2009). The most common measure is manual roster and review (90 per cent), followed by the use of roster design software (70 per cent) and workload monitoring (70 per cent). Education measures are most commonly carried out on pilots (70 per cent), and then management (50 per cent) and rostering staff (50 per cent]. Sixty percent of operators were screened for staff fatigue as part of their FMP.

These results are very much in line with our findings that the most common FMP components are schedule management and education. Attempts to manage sleep disorders are also common. Other FMP elements are feedback on sleep or fatigue levels, with personal advice on coping strategies that might be effective; sleep contracts; attempts to improve the work environment and/or promote napping; and structured organisational learning from fatigue-related incidents.

Guidelines on FMPs have several common elements. Unsurprisingly, schedule management and training and education are the most common, followed by recommendations for health screening and treatment; fatigue policy; and addressing the work environment. However, several guidelines also recommend measures that do not appear to be widely reported by organisations actually implementing FMPs. These include the following:

- fitness-for-duty monitoring
- promotion of an open reporting (‘just’) culture
- competency-based selection and recruitment
- human factors to account for fatiguing conditions
- procedures to ensure that the fatigue of temporary or contract personnel is addressed
- evaluation and refinement against stated aims

Approaches used by authorities attempting to encourage organisations to implement fatigue management include opt-out from hours of work legislation and promoting awareness of fatigue as a risk. In some cases the authority maintains control and implements a program across several organisations itself. However, several “toolboxes” and materials are also available to help organisations develop their own program.

There is a tendency for those organisations reporting FMP implementation to maintain excellent safety records and an open reporting culture before the intervention was made. This raises a question about whether FMPs are being carried out by those organisations which may need them the most.

Resistance to change during programme implementation is a recognised issue, which companies attempt to change using the following measures:

- a fatigue management coach or champion made available to drivers and managers
- a high visibility demonstration project before roll-out across an organisation
- the involvement of all stakeholders from the outset
- multi-level, multi-disciplinary project team to manage the FMP
- end-user participation in FMP design.

Formal analysis of competencies required, and recording of fatigue outcomes over a period before FMP design and implementation are two ways in which future FMP implementations may be improved.

Concerning evaluation of FMPs, the majority of designs are not controlled. The time the evaluation measures were taken in relation to the programme role-out is often not clear. The standardisation of before- and after- periods would help clarify interpretations of evaluations.

Several of the available evaluations were carried out by the people implementing the programme. More independent evaluations are desired.

Most outcome measures reported are training outcomes or reports of subjective fatigue. More reports of fatigue-related behaviour, performance and operational measures – including cost analyses – are desired. Less than a quarter of the FMPs in our inventory report such a battery of outcomes.

There is little comparison of changes in sleep opportunity compared with actual sleep coincinding with an FMP intervention. This comparison is interesting because it would inform about whether schedule changes lead to actual changes in sleep behaviour.

Qualitative reports of FMP interventions are abundant and serve to give some interesting insight into the challenges involved.

Despite the availability of several sets of guidelines, more evaluations of demonstration projects, in which one or more organisations actually implements the guidelines, are required to lend more credibility to the guidelines.

Evaluations of organisational context coinciding with FMP implementation are wholly lacking.

8 The future of Fatigue Management Programmes

8.1 What else do we need to know to scope the problem to be tackled by FMPs?

FMPs are in a relatively early phase of development. The research on which the elements and implementation of an FMP are based is not yet complete. There is a need to further map fatigue states in different occupations and scope the nature of the problem to be tackled. In particular there is a need for research in three domains.

First, there is a need for a better understanding and explicit demonstration of the causative relationship between fatigue levels and safety in occupational driving, in order to help convince organisations to commit the resources required for FMP implementation. A promising development here is in the field of naturalistic observation, where studies are attempting to map the frequency of fatigue incidences in the field in relation to near misses and accidents (Hanowski, Wierwille et al. 2003).

Second, there is a need to map the normal variability in fatigue levels within and between individuals so that this variability can be accounted for by models that predict fatigue risks. Biomathematical models are simplistic and do not sufficiently account for factors which cause intra-individual fluctuations in fatigue proneness e.g. stress or anxiety, sickness or contextual factors such as varying workload or distractions. More research is also needed to understand how these factors interact with homeostatic and circadian processes. In a similar vein, more research is needed to be able to describe behaviourally-anchored competencies to describe a driver that a) copes well with fatigue; and b) is good at managing fatigue. These descriptions could be used to recruit drivers who are better able to cope with fatigue.

Third, there is a need to better understand how causes of fatigue act in combination. There has been much lab-based research designed to study the effects of isolated factors on fatigue. There has been considerable work on fatigue associated with extended duty periods and circadian factors, but we still need to better understand how sleep, time on duty, time of day and physical work together interact to cause fatigue in practice. Knowledge of how circadian effects and sleep quality interact with other crash contributing factors such as traffic, road type and so on is increasing and FMPs will need to apply these findings. On a related note there are calls for more studies to clarify recovery time after accumulated sleep debt (Boivin 2000). The ultimate challenge will be to incorporate findings into models that managers can understand.

8.2 How can we better evaluate the effect of an FMP on a whole system of outcomes?

In every case it is preferable that any evaluation reports a battery of evaluation outcomes, covering subjective and objective fatigue, fatigue-related behaviours and performance, and operational outcomes such as absenteeism, turnover and accidents.

According to Gertler et al (2002), '*Scientific research can validate strategies for preventing, detecting and minimising the performance effects of fatigue. An implementation process, however, is best informed and evaluated through anecdotal or qualitative measures.* (Gertler, Popkin et al. 2002). Indeed, evaluation of FMP is difficult because it involves organisational change, which is complex, in that there are many different trajectories, reasons and circumstances (Hartley 2002). Qualitative evaluation, at least of FMP implemention, is implied. However, we contend that quantitative reporting of organisational variables is also desirable to inform about the nature of the organisational conditions in which the FMP was implemented.

This is in line with Safety Management Systems approaches, which suggest that management will benefit from carrying out computer supported assessments of an array of measures on safety, commitment, job satisfaction, absenteeism etc., that cost savings need to be consistently identified to inform return of investments measures etc.

While cost-benefit analyses have been done based on predicted FMP effects on accidents (Knipling 1998), data of actual effects is needed to better inform these estimates. Cost-benefit analysis is best informed by changes in fatigue-related accidents, since a system with more accidents is often very much more expensive than one without.

In particular, it is important to follow the effects of FMP as they diffuse through the organisational system. For example, evaluation of knowledge and awareness transfer into the workplace and its knock-on effects on driver behaviour over the long term (as a result of training) is a currently neglected area.

8.3 What can be done to standardise different FMP evaluations so that they can be compared?

Evaluation designs that are practical and robust are described in Chapter 6. A simple-to-use and widely available evaluation tool would promote implementation of such robust evaluations, and enable us to reach valid conclusions about FMP effects.

This tool should be constructed through consultation of experts and end-users, and should guide organisations through valid FMP evaluation process. In particular, such a tool should do the following.

- Define an FMP. It would be useful to outline the minimum requirements of an FMP. It is not inconceivable that some organisations may try to use one-off fatigue training in meeting its obligations in fatigue management. Since driver autonomy is not increased, and there is no attempt to increase manager support, one has to question the effect increasing driver knowledge alone would have.

- Address the conceptualisation of fatigue. New scales to assess fatigue are still being published,and it seems timely that a panel of experts settle on and publicise an agreed measure of fatigue. A recent study proposes that this should be multi-dimensional and account for muscular fatigue, boredom, confusion, performance worries, comfort-seeking, and sleepiness (Matthews, Hitchcock et al. 2009).
- Structure evaluations by identifying an evaluation model.
- Describe standard scales for fatigue and organisational measures. This would ease comparisons of different FMP evaluations. For example, the Karolinska Sleepiness Scale could be used for subjective measures of fatigue, and a standard way of reporting sleep debt or fatigue risk could be identified. Recommendations on preferred PVT tests and timing of measures could also be given, and evaluators encouraged to report their results to a centralised database.
- Set out agreed timepoints at which measures should be taken, in order to ease comparison of different FMP evaluations.
- Set out a framework for the description of organisational context into which the FMP was introduced.
- Set out how a system of outcomes can be evaluated, and the benefits of doing this (see above)

To encourage the process, regulatory authorities could support independent evaluations subject to conditional use of the measures recommended by the workshop. If this is not possible then persuasive arguments should be made to organisations, explaining why they should invest in evaluation of their FMPs.

Interestingly, the National Transportation Safety Board in the US is currently evaluating the validity and usability of using a standard evaluation method in the aviation sector (Price 2009).

8.4 What drives and limits FMP uptake by organisations?

We need to know more about what drives an organisation to want to implement an FMP. In carrying out this review we came across few stand-alone organisations who proactively implemented FMPs. This could be because those organisations are few and far between; because they do not tend to evaluate their FMPs; or evaluate their FMPs but do not report their findings. <u>An industry survey would clarify the picture, and identify organisational “drivers” for FMP uptake and implementation</u>. Interestingly, there was also little information on the steps that road transport organisations in Europe make in order to comply with existing hours-of-work legislation. An industry survey could also include questions about this.

No FMP can operate in isolation. It needs to be supported by an operational framework, and the right sociotechnical and cultural conditions in the organisation. Its introduction as part of an existing safety management system would go some way to meeting these requirements and ensure that fatigue-safety is achieved and measured, not as an end-point but as part of an ongoing management process occurring within a systematic framework (Holmes, Baker et al. 2006). <u>A map of how many organisations have these conditions, and which</u>

may therefore be more suited to FRMS implementation rather than a more basic FMP, would be useful.

Furthermore, we may wish to chart those forces which make organisations resistant to FMP uptake. How important is union buy-in relative to management buy-in; what other barriers are there?

8.5 Can company FMPs improve road safety and health in the general population?

It is reasonable to expect that FMPs directed at a wide range of occupations – not just professional drivers – would result in reduced fatigue and thus increased safety during private driving. Improved alertness among employees in general could occur while driving to and from work and in leisure time, for instance, by organisational steps to improve sleep hygiene of employees, or to monitor and control the amount of overtime worked. FMPs could indeed be introduced through any occupational HSE system. In addition, there are several reasons to believe that organisational level interventions to control fatigue in the general driving population would be more effective than more traditional road safety campaign approaches. An organisational approach allows for direct personal contact with the target driver, and this is thought to increase the effectiveness of safety messages (Phillips, Ulleberg et al. 2010). It also offers access to group pressure mechanisms, enables the effects of positive safety culture to be leveraged; and offers the possibility of incentive systems. Despite this, we found only one company-level FMP directed at both occupational and non-occupational drivers [57]. More research is therefore needed to assess such approaches.

As part of an emerging integrated health, safety and productivity model, some FMPs have been introduced as part of company health and wellness programmes (Krueger, Belzer et al. 2007). People at all levels across different industries seem to be more motivated by wellness topics, and several researchers point out that it is important to see fatigue in context of driver wellness (Holland and Leutzinger 2003).

8.6 What are the psychosocial prerequisites of successful FMP uptake and implementation, both at work and at home?

Attempts by the BP Oil programme to increase driver involvement in rostering implies that the company was prepared to give increased autonomy to the drivers, but it was not clear whether measures were taken to actively introduce and support this autonomy.

It is often assumed that driver autonomy is good because it gives them more control over when to take a rest or sleep. However, permitting scheduling autonomy can have unintended negative effects in the trucking industry when it interferes with supplier and customer schedules. It can even be hazardous if drivers choose to drive when they are more likely to be fatigued (Arboleda, Morrow et al. 2003). If drivers are given autonomy, there is evidence that they also need the information and confidence to be able to use their new-found power.

There are other related psychosocial aspects that may be important to programme success. In transport operations in particular, the operator is distant from the supervisor. It may therefore be difficult to established management trust required to accept increased autonomy.

Evaluation of a health and wellness programme in Ruan Transport Management Systems showed that drivers had more positive views of the organisation after the programme, which would also make them more likely to trust and become engaged in an FMP (Krueger, Belzer et al. 2007). This outlines the complex nature of psychosocial conditions for programme success.

Another important psychosocial construct is driver self-efficacy. Put simply, does the driver believe he or she is able to control their own fatigue such that they can drive safely?

If drivers are not involved from the start in FMP development, there is evidence that they may not be interested in encouraging the implementation of learning (Griffin and Neal 2000). Given this point it is encouraging that many of the FMPs and guidelines in our inventory appear to involve drivers early on.

A study that aims to pinpoint the role and importance of the above factors in the effectiveness of programme implementation would be useful.

8.7 How can FMPs be adapted to suit different organisations?

It is thought that FMPs will be most effective if the drivers and managers cooperate and respond to feedback and information together in a devolved, open culture, with high levels of trust. One can question whether such a culture is the norm for most transport companies. If this is true, then what are the different contingencies for effective FMP implementation?

Are organisations with a highly prescriptive culture able to take advantage of the increased empowerment often associated with more progressive FMPs? With such organisations, is it better to train schedule managers in fatigue and increase driver awareness about fatigue rather than involve drivers in schedule management? How should the values, motivations and other variables describing an organisation be mapped in order to describe the best-suited FMP intervention?

Most organisations that introduce fatigue modelling "*do so in the context of a pre-existing prescriptive approach to fatigue management [in which fatigue is modelled] in a semiprescriptive manner superimposed on top of the pre-existing culture*" (Dawson, Noy et al. 2010). Maximum fatigue risk scores are prescribed, with the result that traditional notions of shifts are merely recapitulated. What organisational or other conditions will prevent this happening?

The funds available to an organisation also need to be considered. Even with BP's resource, only the largest of six sites was able to implement a fatigue-related accident database. Anecdotal evidence from the Queensland Transport FMP pilot also suggests that some companies find the costs of FMP implementation too high. In this respect <u>it would be useful to know which elements of an FMP are most cost-effective</u>.

Some organisations recommend FMPs should form part of an employee assistance programme, emphasising the importance of family involvement, some that it should be part of risk assessment or safety management system, some that it should be part of occupational health approach. Is each approach best suited to certain types of transport organisations?

8.8 What are the ethical challenges for organisations implementing FMPs?

A recent paper states that the future of fatigue management is dynamic scheduling informed by data generated by the continual monitoring of an individual driver's sleep patterns, fitness-for-duty patterns, and fatigue development while driving (Balkin, Horrey et al. 2010). What do drivers, driver unions, and society at large think about monitoring the sleep drivers get while they are at home? Is there a role for pharmacological stimulation in an FMP?

8.9 Some recommendations on how to improve FMPs

The inventory outlines several attempts by governments to gather union and industry support, and promote collaboration for demonstration FMP projects. Efforts in this direction are encouraged, but more work is required on factors that encourage and hinder organisational uptake of FMPs (see above).

FMPs would be well served by achieving the following steps.

1. Through consultation, evidence, operational considerations, design a schedule, job and work environment in which the driver can reasonably be expected to enjoy, thrive and not get too fatigued for safe driving.

2. Give the driver support in the form of job control and resources to be able to manage his own fatigue.

3. Account for driver's social milieu, including families and friends, and drivers from other organisations and the driver's own organsiation.

We place rather more emphasis on the last two steps than is common in the literature for the following reasons.

First, as a recent review points out, fatigue is not a conventional chemical or physical hazard and cannot therefore be managed through normal risk assessment processes (Gander, Hartley et al. 2010). Fatigue is something that the driver takes home and brings with him to work. It is affected by what he does at home and at work. Regulators that insist that managers manage and control risks of fatigue are saying that the organisations need to put in place measures to control the hazard, but given that the hazard transcends all aspects of a driver's life one can question how far a company can go in order to control the hazard. In fact the only person that has the potential to control all causes of fatigue is the driver. This implies that the company's main role should be regulative and supportive: driving limits need to be set, fatigue levels monitored, and the driver given the organisational support, information and tools they need to be able manage their fatigue. The company should seek to say *what* the employee should aim for in terms of fatigue levels at work, and monitor to check that employees stay within those limits. They should then seek to do achieve two things: (i) ensure that the work itself will not produce high levels of fatigue; and (ii) support the employee with the tools, information and feedback they need to be able manage their fatigue at home, at work and while travelling in between. This support should aim to ensure that employees are aware of the *danger* implicit in signs of fatigue while driving and are motivated to do something about it that will have an effect (Nordbakke and Sagberg 2007). It is the employee who should ultimately decide *how* safe fatigue levels are achieved.

Second, drivers receive a low degree of social support, often have high physical demands, have demands on sustained attention and perform monotonous and narrow tasks. Drivers are largely controlled by their environment. Giving the driver the chance to control their fatigue may lead to a change that they are highly motivated to conduct. Improvements in skill variation, autonomy, feeback, task identity (increasing wholeness of task), task significance (having impact on others), and feedback are all condusive to high levels of performance and wellbeing. These factors may in turn have important repercussions for fatigue.

Many FMPs in our inventory describe FMP design in consultation with drivers. This is also to be encouraged because the FMP should from the outset attempt to address the problems in consultation with the owner of the fatigue. Do the drivers ever feel fatigued? When? What causes it?

We would also like to challenge the central role of technology predicted for future FMPs. It is worth asking whether there are cases where social solutions would be more effective e.g. creating a culture of trust where drivers openly inform on the amount of sleep they have had, instead of fitting them with an actigraph.

Other ways to improve FMPs can be summarised as follows:

- Create a tool to match FMP elements to organisational type
- Consider an FMP training element that gives drivers experience of fatigue without exposure to increased fatigue risk
- Better consideration of temporary and contract workers
- Exploit valid (construct, face, predictive), usable, accepted, practical, reliable, cost-effective technologies to assess fitness for duty as they become available
- Address a paradox between need for speedy delivery and need for rest (conflict between fatigue management and logistics). FMP components need to be contingent with each other, with pay, selection, performance and assessment.
- Address how to increase the visibility of driver fatigue as an issue to all stakeholders
- Better education of managers about what software does so they do not over-interpret its findings
- Ask whether train-the-trainer approaches are valid
- Increase the extent to which competencies are analysed and used as basis in FMPs
- Consider employee incentives in FMPs
- Consider incorporation of FMPs as part of normal HSE management in all types of companies as a way to improve on the limited impact of road safety campaigns.

9 Overall summary

Fatigue is a major cause of crashes involving occupational drivers. A review of research on fatigue in occupational driving in Chapter 2 suggests there are influences at various levels.

The way organisational influences affect fatigue will ultimately be moderated by the driver at the individual level. Individual physiology, hardiness, habits, attitudes and beliefs together with psychosocial influences that transcend working life will be key in determining the extent to which a driver exploits a given opportunity for sleep, whether they will be fit-for-duty given a certain sleep history, and whether they will be able to perform safely given a certain fitness for duty. This is illustrated by Figure 1.

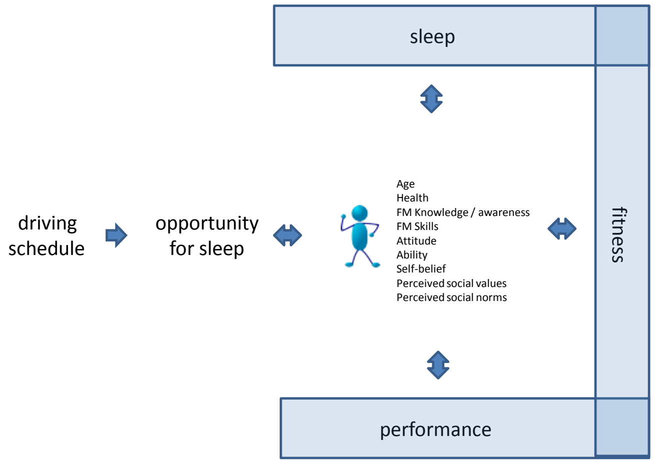

Figure 1. Effects on driver fatigue. A driver schedule has an important influence on fatigue, primarily by affecting their opportunity for sleep and the time of day at which they drive. However, how much and how well a driver sleeps given a certain sleep opportunity will ultimately affect fitness for work and task performance. A driver's interpretation of the need for rest before work; the actual sleep obtained; how fit they are for work given a certain quality of sleep; and how well they perform given a certain level of fitness-for-duty will depend on several factors at the individual level. FM = fatigue management. Source:

A key part of this moderation process will be (a) the driver's interpretation of their own need for sleep and their own ability to be fit for duty and perform given a certain amount of sleep; and (b) the extent to which drivers believe that inability to perform will lead to increased accident risk.

It is only the driver who can ever have a complete oversight over the influences of fatigue, and who can ever have complete control over those influences. However, the organisation has an obligation and responsibility to drive, guide and support the driver in this task. It should do so using a system of measures.

Of those factors under organisational control, fatigue will be most influenced by the driver schedule, which delimits the extent to which driver can recover from previous work and prescribes the time of day at which the driver must drive. Organisational training, coaching and feedback about own fatigue levels will influence the way a driver make key interpretations about sleep and fatigue, and will therefore also be important. Fatigue levels of the driver will also be influenced by psychosocial influences at work, by the extent to which their job gives them control over sleep and rest patterns. Selection and recruitment processes will also help filter out those drivers who are less likely to behave safely or who are more prone to fatigue.

Ultimately, the organisation should seek to engage the driver in fatigue management, and work together with the driver in managing fatigue by providing the organisational conditions, information, auditing, procedures, systems and tools needed to do so in a documented and effective manner. In helping the driver perform safely at work the organisation should focus auditing and tools particularly on two areas: (i) checking that employees are optimally fit for duty, and taking non-punitive action if they are not; and (ii) checking for fatigue developing during a trip and triggering countermeasures as necessary.

In helping the driver the organization will need to understand the way its own processes influence driver fatigue. This will require monitoring of fatigue influences in relation to driver fatigue levels, behavioural measures of fatigue (monitoring of physiological indicators of fatigue, cognitive testing, driver performance on the road) and organisational outcomes, such as incidents, near misses, accidents, turnover, absenteeism or health.

In implementing fatigue management it is important that organisational prerequisites are in place. These include a fatigue policy referencing written procedures and detailing lines of responsibility, and the results of an analysis of the fatigue issues faced by the organisation. It will be important to ensure that the safety culture and climate are aligned with the fatigue management measures proposed in the FMP. It will also be important to ensure those who have new responsibility for controlling fatigue have sufficient autonomy, information and feedback. Thus, organisational change will often be a key part of any FMP roll-out.

Invariably, the FMP elements selected by the individual company should be based on the findings of a needs analysis in which subjective fatigue, driver sleep, behavioural indicators of fatigue and/or driving performance are recorded over a period before any management intervention.

Analysis in Chapter 3 shows that four general measures are available to help manage fatigue in organisations. These are:

- Training or coaching to increase awareness, improve attitudes, change behavior;
- Scheduling to account for fatigue;
- Addressing how health influences fatigue; and
- Addressing organisational influences on fatigue.

In Chapter 4 we saw that there are many tools and technologies available to help implement these measures. There are training materials and software tools to help managers account for fatigue in scheduling, as well as devices to help monitor fitness for duty. Devices to detect and assist drivers who are fatigued are nearing realisation. There are also organisational tools for developing fatigue policy, carrying out a programme needs analysis and developing competencies for use in selection and recruitment. However, no tool is available that helps FMP elements to be selected according to the particular contingencies of the organisation.

In Chapter 5 we described the growing need for and recent growth of FMPs as a way to manage fatigue at the organisational level. Fatigue management has been encouraged by research evidence and regulatory bodies.

There is a hope that FMPs will lead to a more motivated and effective management of fatigue, and accordingly there has been a movement of responsibility from authorities towards transport companies, and even individual drivers within organisations. Such a shift seems sensible since it moves responsibility towards those who have the greatest understanding and insight into the causes of fatigue, namely the drivers themselves, and those responsible for their schedules and working conditions. Despite this hope, it is likely that FMPs will seem expensive and daunting, especially to managers in smaller companies.

To judge whether FMPs will be as effective as hoped, we need many robust evaluations of FMP implementations by road transport companies. In Chapter 6 we described practical evaluation designs, and showed that reports of organisational context are required if we are to begin understanding which types of organisation are best suited which types of FMP element. To assist this, we suggested that regulatory bodies should consider in particular promoting and supporting evaluations and reporting of those evaluations by organisations.

Each evaluation should seek to report a battery of evaluation measures describing the effects of the FMP intervention. They should cover subjective and objective fatigue levels, fatigue-related performance and fatigue-related operational variables. The cost-benefits of the FMP should also be reported. Additional measures should address the effectiveness of job design or culture changes attempted as part of the FMP.

In Chapter 7 we reviewed an inventory of 61 FMP interventions. The most common FMP components were schedule management, education and sleep disorder management. Thus it would appear that the FMPs reported employ elements described in the research literature as serving to tackle the causes of fatigue. Encouragingly, this suggests that current FMPs are indeed evidence-based.

Furthermore several FMPs incorporate additional elements, which promote the management of fatigue by the driver. These include feedback on sleep or fatigue levels, with personal or training advice on coping strategies that might be effective; and sleep contracts.

Guidelines on FMPs have been issued by authorities or institutes. Although they are nearly always evidence-based, an example evaluation of the effect of implementing the guidelines is not normally given. In line with our findings, the guidelines emphasise schedule management, education and health management as key elements of an FMP. Commitment to fatigue policy and a need to address the work environment are also emphasised, and these elements are not uncommon in FMPs actually implemented by organisations. However, several guidelines also recommend measures that do not often appear in reports by organisations actually implementing FMPs. These include the following:

- fitness-for-duty monitoring
- promotion of an open reporting (‘just’) culture
- competency-based selection and recruitment
- human factors to account for fatiguing conditions
- procedures to ensure the fatigue of temporary or contract personnel is addressed
- evaluation and refinement of the programme against stated aims

For FMP implementation, resistance to change is a recognised issue. Transport companies have attempted to tackle this using nominated fatigue management coaches or champions; visibly effective demonstration projects; involvement of all stakeholders from the outset; multi-level, multi-disciplinary project teams; and end-user participation in FMP design.

As recently as 2005, there were claims that “FMP evaluations have been strictly subjective” (Moscovitch, Reimer et al. 2005). Given a review of our inventory, there are some objective indications that FMP outcomes are positive. However, objective outcomes are usually expressed only in terms of knowledge or awareness of fatigue. We still know little about the effect of FMPs on driver performance or operational outcomes. The majority of FMP evaluations reported are not controlled. The time the evaluation measures were taken in relation to the programme role-out is often not clear. Standardisation of time before- and after-periods would help clarify interpretations of evaluations. More independent evaluations are desired, as are more reports of fatigue-related behaviour, performance and operational measures – including cost analyses. A comparison of changes in sleep opportunity compared with actual sleep coinciding with an FMP intervention would be particularly informative, but is rarely given. Evaluation of changes in organisational context is also lacking, although qualitative descriptions of the intervention are often given and are encouraged.

In setting out our recommendations for future work in the last Chapter, we claim that there is a need for a better understanding of the causative relationship between fatigue levels and safety in occupational driving; and a need to better understand how causes of fatigue act in combination. We cannot expect to be able to fully convince organisations to commit the resources required for FMP implementation while we do not have this understanding.

Better mapping of the normal variability in fatigue levels within and between individuals would improve fatigue risk predictions by scheduling software, which is proving popular among managers. There is a need for these managers to be better trained in understanding the basis and limitations of this software.

More robust, independent evaluations of FMPs are required that chart the effects of FMP as they diffuse through the organisational system. Generalization about FMP effects, the organizational context into which the programme was implemented needs to be described quantitatively and qualitatively. Cost-benefit analyses of FMPs are required, and these would be best informed by changes in fatigue-related accidents.

A simple-to-use and widely available evaluation tool would promote implementation of robust evaluations reach and enable us to reach valid conclusions about FMP effects. Such a tool should be prepared by a workshop of experts and end-users. The tool should define what an FMP is and is not; conceptualise fatigue; structure evaluations using an approved evaluation model; recommend standard scales for measures of fatigue and organisational indicators; recommend timepoints at which measures should be taken; provide a framework for fatigue outcome evaluation, and evaluation of organisational context.

While our inventory contains several examples of FMPs carried out by companies with pre-existing high safety standards, we know very little about what the vast majority of road transport organisations do to manage fatigue and comply with existing regulations. An industry-wide survey is required to chart existing contexts into which FMPs are expected to be introduced. Only then can we know which FMP elements will be more suitable. This would also give us a better understanding of those factors increasing and decreasing the change that an organisation will implement an FMP. In preparation for the results of this survey it would be useful to know which elements of an FMP are most cost-effective for those companies with limited resources.

We have documented reasons why organisational level interventions to control fatigue in the general driving population could be more effective than more traditional road safety campaign approaches. This report gives several lessons for such interventions, and catalogues elements that could be used. There is room, however, for a more detailed consideration of general organisational interventions to tackle driver fatigue. For example, which elements would be most appropriate for which occupations? Should general FMPs be incorporated as part of a company’s HSE management system? Should organisations monitor fatigue of staff who are not occupational drivers but who may drive long distances to and from work?

Finally, other ways to improve FMPs included the following:

- Create a tool to match FMP elements to organisational type
- Better consideration of temporary and contract workers
- Exploit valid (construct, face, predictive), usable, accepted, practical, reliable, cost-effective technologies to assess fitness for duty as they become available
- Address a paradox between need for speedy delivery and need for rest (conflict between fatigue management and logistics). FMP components need to be contingent with each other, with pay, selection, performance and assessment.
- Address how to increase the visibility of driver fatigue as an issue to all stakeholders
- Increase the extent to which competencies are analysed and used as basis in FMPs
- Consider employee incentives in FMPs

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Appendix A – FMP Inventory

1 Land Transport Safety Authority FMP for lorry drivers (New Zealand, ca. 2002)

*Sourc*e: (Jettinghoff, Staren et al. 2005)

Involved regulators / organisation(s): Various trucking companies representing 250 drivers involved.

How fatigue is addressed: Not known.

Evaluation outcomes: Pre- and post-FMP qualitative assessment by stakeholders of costs and fatigue effects. No other details available from source used.

Description: Trial FMP project developed in association with experts in the field. Nature of project and demands required of the companies declared in 'manuals'. These include an application and approval process that if successful becomes a documented FMP with which an accreditation can be obtained and an exception to the standard driving hours for that company. Drivers, manager and traffic coordinators concerned are expected to fill in a confidential questionnaire at beginning and end of trial project. From these the impact of the programme on fatigue and economic impact are to be determined. Gander & Leigh at Massey Sleep/Wake Research Centre stand for the research evaluation.

2 ATRI Alertness and Managing Driver Fatigue train-the-trainer programme (USA, 1996)

Source: (Jettinghoff, Staren et al. 2005)

Involved regulators / organisation(s): Developed by American Transportation Research Institute (ATRI), financed by Federal Motor Carrier Safety Administration (FMCSA). Participants recruited through the ATA (American Trucking Association) and 50 different state trucking associations.

How fatigue is addressed: Knowledge and awareness of fatigue; coping strategies; management of sleep disorders.

Evaluation outcomes: Trainer knowledge tested after immediately after their training, and driver knowledge tested three months after training delivery to trainers.

Description: Managers in a certain bus or lorry organisation are trained to train their own personnel (drivers). Training lasts one day in which the trainers get instruction in the morning about fatigue and information about health in the afternoon. After that they give training to their drivers, and how this is done is a matter of interpretation for the individual trainer and / or organisation. Five thousand trainers have followed the training, but it is not known how many drivers because the organisations were not willing to pass on that information.

3 HFCC Operator Fatigue Management Programme (USA, 2004-)

Source: (Jettinghoff, Staren et al. 2005); http://hfcc.dot.gov/ofm/

Involved regulators / organisation(s): Human Factors Coordinating Committee (HFCC) of US Department of Transportation (DOT). Government, industry, and labor in partnership.

How fatigue is addressed: Knowledge and awareness of fatigue; scheduling of sleep opportunities to increase the chance of proper restitution; accompanying business changes required to address fatigue.

Evaluation outcomes: The individual tools are being evaluated but no details as yet on website.

Description: Partnership to create tools to aid in industrial understanding and managing of operator fatigue. A compendium of current science and practical information on approaches to fatigue management and mitigation in the transportation enterprise. There are five tools: Work schedule representation and analysis software; Business Case tool; fatigue model validation; fatigue management reference. These are presented in a non-prescriptive approach to help organisatons deal with fatigue among their employees. For example, the roster evaluation software is described and given along with relevant rules and facts about fatigue. The software allows rosters to be compared, and describes good and bad rosters in terms of fatigue management. The software is accompanied by a training programme leading to certification as accredited user of these devices. Trained advisers are identified that could be used as consultants by small organisations. The Fatigue Management Reference Guide, the OFM programme's most recently completed tool, was finalized in January 2004 at a special meeting attended by project representatives from both the DOT and the Department of Homeland Security. The guide begins by detailing **operational fatigue risk factors**. These are extended work and commuting periods; split-shift work schedules; sleep/work periods conflicting with circadian rhythms; rotating or changing and unpredictable work shcedules; lack of rest opportunities during work; sleep disruption; inadequate exercise opportunities; poor diet; environmental stressors (noise, vibration, cold, heat). The **components of a good FMP** are then described and detailed. These are organisational commitment; employee-employer partnership; education & training; employee health screening; programme evaluation and refinement. **Organisational commitment** is visibility and support at the highest levels in the organisation, sufficient allocation of resources by management and involvement of senior executives in formation and execution of effective policy eg listing objectives, responsibilities, expertise, evaluation methods. **Employee-employer partnerships** aim at finding a means to ensure that the two parties are effective when they work together. **Education and training** should address the physiological mechansims and recommendations for countermeasures, as well as information on how to foster behavioural change.**Health screening** should be done to screen for fatigue states and sleep disorders confidentially and using support material eg American Trucking Association’s Alert Driver Guide includes a chapter Do You Have a Sleep Disorder? Finally, the programme should be **evaluated and refined** against objectives. Measures should include hours of charged operator overtime, average sick days, number of fatigue accidents and incidents, attendance at educational events, number of fatigue screens, operator response to periodic alertness management survey. Finally the guide lists details of different **countermeasures** that work (sleep, caffiene, napping, trip planning, good sleeping environment); that work and require medical supervision (bright light, stimulants, sedatives, hypnotics, melatonin); that are ineffective or dangerous (nicotine, ventilation; temperature; exercise; diet; sound; odor; over-the-counter sleep aids); and are in development (models of alertness; fitness for duty testing; alertness maintenance monitoring).

4 HSE guidance on fatigue management (UK, 2005-)

Source: (Jettinghoff, Staren et al. 2005); www.hse.gov.uk/roadsafety/index.htm

Involved regulators / organisation(s): Ministry of Transport (THINK! campaign); Occupational Road Safety Alliance (ORSA); HSE.

How fatigue is addressed: Where fatigue is assessed to be a risk, ways to prevent fatigue occurring must be considered.

Evaluation outcomes: The effect of treating fatigue as a risk to be assessed within an Occupational Health & Safety framework on fatigue levels or accidents is not known.

Description: In the UK employers have a legal duty towards the traffic safety of their employees; it is a work-related risk to be assessed and managed (the legislation does not cover travel to and from home). Guidance is therefore focused on how to do a risk assessment. The term ‘fatigue’ is not listed as a safety topic on the websites guidance index. The HSE website does, however, give a toolkit for organisations to help them tackle fatigue, as well as facts and figures and the Safety Culture Programme of the Ministry of Transport.

5 Swedish Army “Noll Noll” Programme (Sweden, ca. 2005)

Source: (Jettinghoff, Staren et al. 2005)

Involved regulators / organisation(s): Swedish Army.

How fatigue is addressed: Employees given feedback and awareness of own sleep quantity and quality; knowledge given on causes of fatigue.

Evaluation outcomes: Anecdotal evidence that accidents due to falling asleep have been reduced to ‘practically nil’, but no information on pre-intervention levels.

Description: Employees given feedback from sleep-monitoring device on own sleep-wake patterns, and information on off-duty behaviour that can lead to fatigue.

6 Colour-coded fatigue risk management (Multinational, ca. 2005)

Source: (Jettinghoff, Staren et al. 2005)

Involved regulators / organisation(s): Shell

How fatigue is addressed: Journeys are assessed for factors that are likely to cause fatigue, and the risks managed as necessary.

Evaluation outcomes: Not known.

Description: Shell uses a colour-coded system for the assessment of fatigue by drivers and their supervisors. In this system '3 orange = 1 red'. When an employee assesses that a planned or ongoing journey has three or more points of danger, he or she has to change an aspect of the journey or stop. One of the danger points must then be addressed (changed to green) before the journey can go ahead. For example, if an employee must take a long flight (1 orange) and then drive a long way (2 orange) on the wrong side of the road (3 orange) the person must do something about one of these points of danger, such as breaking up the distance driven.

7 US Army sleep management system, (USA, 1998)

Source: (Belenky, Balkin et al. 1998); http://wrair-www.army.mil (accessed 10.03.10)

Involved regulators / organisation(s): Walter Reed Army Institute of Research

How fatigue is addressed: Feedback to personnel, including army drivers, on own alertness levels to raise awareness of fatigue / scheduling by supervisors for sufficient quality and quantity of sleep.

Evaluation outcomes: No evidence of evaluation found in an on-line search.

Description: A wrist-worn sleep monitor (actigraph) is used to measure the quantity and quality of sleep obtained by military personnel under operational conditions. The monitor includes software that uses a biomathematical model to predict performance from the sleep data. An "on-line, real-time" monitor of alertness is also used to warn the soldier and their superior of an imminent failure in performance, which can then be managed using stimulant drugs (when sleep is not possible) or sleep (when sleep is possible). The system also aims to better account for sleep requirements when planning operations, and to give the wearer information on his or her current sleep and predicted performance state. The model incorporates the results of experimental studies (presumably the army's own) on the effects of sleep deprivation and circadian rhythm. Sample prediction curves are given showing artillery battery performance changes for a soldier sleeping 4, 5, 6 and 7 hours of sleep a night from 1 to 20 days of operation.

8 Educational Programme for air traffic controllers (Canada, ca.1998)

Source: (Heslegrave 1998)

Involved regulators / organisation(s): Transport Canada, Transportation Development Center, Rhodes and Associates Inc.

How fatigue is addressed: Knowledge of practical strategies for better sleep given to shiftworkers, based on extensive survey and performance measurement of shiftworkers.

Evaluation outcomes: Training not complete at time source published. No evidence of evaluation found on searching Transport Canada website (www.tc.gc.ca).

Description: This is a multi-year project in three phases: (i) a literature review and comprehensive survey of almost 2000 operators to examine perceived impact of shiftwork on job performance, sleep, somatic complaints and job satisfaction. Importantly the survey was designed in collaboration with operators and managers. Operators reported that midnight shifts resulted in less sleep prior to shift and worse performance. Those over 35 reported less sleep and worse performance. The second phase sought to quantify objectively the effect of different shift types on performance and this confirmed the performance impairment was worse for the midnight shift. At time of report (1998) third phase, an educational programme for controllers modeled after a book for shiftworkers was underway.

9 BP FMP for 230 tanker drivers across 6 sites (New Zealand, ca.1995-2002)

Source: (Gander, Waite et al. 1998; Gander, Marshall et al. 2005)

Involved regulators /organisation(s): BP Oil New Zealand, independent evaluation by Otago University at Wellington School of Medicine.

How fatigue is addressed: Driver survey to map current fatigue problems and rostering practices in company. Use above survey results and involve drivers in developing rostering guidelines that better account for fatigue; and also consider time-on-task; sleep debt from consecutive shifts; and timing of circadian troughs. Knowledge on fatigue prevention and fatigue coping strategies given to drivers (train-the-trainer) in a two hour presentation including sections on physiological basis of fatigue; influence of circadian cycles; effects of shiftwork; impact of fatigue on driving skills and crash risk; recommendation for personal countermeasure strategies; and company policies with regard to workplace napping; referral to specialist for sleep disorder treatment; ending with discussion session. Managers also educated to align them with drivers; help them maintain successful FM strategies. Improved scheduling to account for time-on-task; sleep debt from consecutive shifts; and timing of circadian troughs. New process to build database of role of fatigue in accidents and guide company-tailored FM strategies. Modification of company medical exams to collect data on individual risk factors for fatigue. Other activities include provision of napping kit (neck pillow, eyeshades, alarmclock) and a procedural checklist to keep in vehicles;

keyrings with anti-fatigue messages; and a developing website where drivers can describe their own experiences.

Evaluation outcomes: Driver training field tested with 12 participants. 90 per cent expressed positive intentions to change behaviour. New rosters suggested by employee responses created problems for logistics managers. Further evaluation given in later publication (Gander, Marshall et al. 2005), in which assessment of fatigue management training for BP distribution contractors (heavy vehicle drivers of which over 80 per cent shiftworkers) or BP Oil NZ Ltd (light vehicle drivers). Two main measures to evaluate training: i. short quiz on key concepts that was administered before and after every training session, to examine immediate knowledge transfer; ii. Survey of BP distribution contractors, 1-26 months after training. This examined driver knowledge and use of fatigue countermeasures, and their views on the usefulness of training. Scores on i. improved from 9/16 to 14/16 (n=275 heavy vehicle. In ii. drivers reported less problems sleeping and comparable sleep disorders when compared with others of their demographic in the population. 31 per cent reported changing sleep habits at home; 16 per cent reported changing break patterns at work, 14 per cent reported changing diet at home; Few drivers reported changing rosters, caffeine use, number of trips.Were changes due to training though? Light vehicle drivers thought training more useful than heavy vehicle drivers, but even latter rated it as useful to some extent. 61 per cent of heavy vehicle drivers wanted more training. In a 1996 survey prior to fatigue management training 20 per cent of HV drivers had ESS > 10, compared to 13 per cent in the 2000 follow-up survey, despite an increase in shiftwork

Description: Development of this comprehensive, integrated programme was based on the NASA Fatigue Countermeasures Programme (Rosekind, E.L. et al. 2002). The FMP is in two steps: i) a driver survey to map fatigue problems and rostering practices in company, and to identify any links between them; and ii) a package of measures to begin countering fatigue in the organisation. These measures are as follows.

- The first measure is a two- page form to help investigators collect information on fatigue involvement in company accidents, to identify particular risk areas and guide tailored FM strategies. This is based on a method by the National Transportation Safety Board in an aircraft investigation in 1994. The aim is to collect information on time since last sleep; length of last sleep; cumulative sleep debt; sleep disorders; time of day of accident. To do this a sleep and duty history are collected for each driver for the 3 d prior to the event. Additional information is sought on snoring, subjective sleepiness (Epworth score), driver assessment of status at time of event. A manual is available on how to use the form. Eventually it is hoped that a de-identified and company-tailored database can be built up on the role of fatigue in incidents and accidents. However, only the largest company was able to carry out this measure.
- Train-the-trainer workshop (over 2 d). The trainers, who are managers, health and safety officers and driver representatives, educate drivers in two-hour sessions about fatigue causes and why this is a problem in trucking. Evidence-based knowledge is used to explain how drivers “can arrive at work in the best possible condition” and maintain alertness once

at work. A handout is provided. More details above. The training was field tested. Short-term effectiveness of knowledge transfer was assessed.
- One-day workshop to educate managers to align them with workforce and help them maintain successful FM strategies
- Modification of company medical exams to collect data on individual risk factors for fatigue
- Use above survey results and involve drivers in developing rostering guidelines that better account for fatigue. (This was ongoing at time of the 1998 source publication.)

The programme is informative in its attemtps to draw up guidelines that allow rostering to be done by the drivers themselves, or sub-contractors and owner drivers. Survey data and current evidence on fatigue and suggests a need to delimit a 12 h day-shift and 10 h night-shift. This is, however, logistically suboptimal because trucks would not be in use 24 hours a day, leading to higher costs. There are also logistical considerations (availability of loading facilities, local traffic patterns) limiting timing of shift handover in relation to timing of circadian rhythms. To limit the accumulation of sleep debt reported by some drivers, the preliminary guidelines suggest that no driver should have more than five consecutive shifts without two nights of unrestricted sleep. The guidelines also suggest rosters should be predictable to allow for social and family planning, to develop support networks that may be important when coping with shiftwork. Driver education is seen as an important prerequisite to the involvement of drivers in roster design. It is notable that the organisation clearly supports giving drivers increased autonomy.

10 Queensland FMP pilot I (Australia, 1998)

Source: (Mahon 1998; Burgess-Limerick and Bowen-Rotsaert 2002; NTC 2006; Williamson 2008)

Involved regulators / organisation(s): Queensland Transport, regulator for the state of Queensland. Evaluation by independent consultants, Institute of Workplace Training and Development. Funded by Federal Office of Road Safety. Pilot project overseen by a project team comprising representatives from road and traffic authorities, enforcement agencies and industry from all parts of Australia, and a research consultant (Dr Anne-Marie Feyer). Pilot involved 1000 drivers from 16 organisations, although evaluation outcomes not always measured in all organisations.

How fatigue is addressed: Transport operators must demonstrate and document an effective FMP comprising the following elements: **Scheduling**. Must incorporate FM measures and give drivers flexibility to reschedule driving / rest periods. **Rostering.** Must incorporate FM measures and assign drivers in accordance with recent work history, welfare and preference. **Time working.** Must demonstrate that scheduling and rostering techniques are being practiced by keeping accurate records of each driver's time working and rest activities. **Readiness for duty**. All drivers must be in a fit state to perform driving and other duties. **Time not working.** Must be sufficient to recover from fatigue generated by time spent working. **Health.** Health management and screening system must be in place to prevent / combat onset effects of fatigue, address sleep disorders, other relevant health issues. **Management.** Management must ensure all drivers suited to the transport task and there are open lines of communication on matters that enhance safety. **Workplace conditions.** Must assist in fatigue prevention. Fatigue **training and education** of drivers and management. Also vehicle safety, documentation of FMP policies, procedures for non-compliance, record keeping, internal audits make up the programme.

Evaluation outcomes: No pre-intervention measure in evaluation of Phase 1 results (see below). Drivers of organisations in Phase 1 together drove over 12 million km without fatigue related accidents, though no detail on definition of such accidents was given. Before the FMP, one organisation had experienced two such accidents. 15 out of 480 interceptions of Phase 1 FMP drivers resulted in follow-up action. Of 32 Phase 1 drivers surveyed 88 per cent report control over where and when they stopped; 40 per cent felt tired on at least some trips; over half said they were never impaired by fatigue; 90 per cent said they would tell a supervisor if too tired to drive. FMP was reported as 'also beneficial on business efficiency'. According to anecdotal evidence, the consultation phase in FMP development within companies improved communication between drivers and managers, leading to increased morale among drivers. Operating under the FMP, drivers felt they could report truthfully their activities because they did not fall outside the law. Increase in vehicle utilisation was reported, along with an improved ability to meet customer requirements. FMPs were also being used as a requisite for transport operators tending for large contracts. Sometimes, however, FMP operators were undercut by unscrupulous operators. Problems noted with FMP pilot included that the administrative burden was too high, with increasing costs resulting; there were not enough rest facilities to allow drivers to exploit their new autonomy to the full; and the way accidents were reported made it difficult to know how many were fatigue-related. A pre-intervention measure was planned for Phase 2 evaluation, which was yet to begin when Mahon (1998) was written. The 2008 report gives an **independent evaluation** based on six of the participating companies, in which pre- and post-intervention measures were taken from each organisation, the latter five years after intervention began, and compared to those from **control** organisations which did not have an FMP. It was found that drivers were more likely to report involvement in scheduling after the intervention but less likely to report the following: that they are tired before or while driving; that they notice indicatiors of fatigue; that they need to use countermeasures while driving; not knowing enough about fatigue. Management reported a more proactive role in scheduling, that they liked that drivers were involved, that they perceived fatigue levels had decreased. Four of the companies found they operated more efficiently, though changes in revenue could not be attributed to the FMP. Companies recognising it as successful say driver buy-in to FMP is key; customers understand the business better; increased focus on customer and driver. Negatives were standardising rosters, changing driver culture; initial driver negativity, getting drivers to participate in training and medicals; lack of knowledge among enforcement officers, scare campaign from union, drivers wanting extra shifts, administrative effort, costs (700 AUS D per driver per annum). Find that drivers manage their own fatigue on-road, but perhaps the biggest impact is from driver managers monitoring readiness for duty. Schedules managed largely by drivers, just approved by managers with respect to customer needs.

Description: The hours of service regulations in Queensland at the time of the pilot were 12 h driving/d; a minimum 9 cumulative h rest in any 24 h, of which 6 h must be consecutive; a maximum of 5 consecutive h of driving prior to taking at least a 30 minute break; a maximum of 72 h driving in 7 days; and driver logbook completion. The alternative FMP model was as follows. FMP operators enter into an **accreditation agreement** with Queensland Transport, which allows them to operate outside of prescriptive regulations in exchange for agreeing to certain terms and conditions. These outline that they must operate a comprehensive management arrangement to meet fatigue based performance outcomes. In addition, **FMP standards** are described for the operator to help them manage all factors causing fatigue. These standards form the basis of **FMP audits**, and an operator must show that the systems and procedures they put in place will meet the standards. The standards are listed above under 'How fatigue is addressed'. In anticipation of phase 2, the model was refined to include **outer operating limits** (max no. hours work over 24 h; min no. night's sleep in 7 d period; max number of aggregate work h). These are set and justified by the organisation itself to afford a level of flexibility from normal operating limits. For each work and rest parameter, the operator will nominate a normal and outer limit value. The business is planned and organised around normal limits. The outer limit provides a mechansim to signal when countermeasures may be required e.g. extra rest, follow up investigations etc. Each operating limit is assigned a frequency which is the max number of times an outer limit can be breached by an individual driver (e.g. once a month). These frequencies will be a gauge of the effectiveness of an FMP. The model was also refined to include **performance management** model for Queensland Transport so they can show to interested outsiders that the FMP by a particular operator is enforced and works. Components of performance management are audits, on-road enforcement and sanctions. One audit is carried out on entry to the FMP scheme, to ensure systems are in place; another 3-9 months after entry to see whether the operator has met the terms of the accreditation agreement; random audits by enforcement officers.

FMP drivers can operate outside of the regulations whilst they meet the conditions of the programme, and are not therefore subject to logbook offences. The FMP is designed to allow operators to report on and manage breaches itself. However, on-road enforcement is used to check for serious breaches, which the government can intervene and act on by taking corrective action, suspending operators, cancelling FMP accreditation.

In the first phase of this project, several operators were involved in designing and developing an FMP model. Three transport operators operated successfully for 18 months using the pilot FMP. The project therefore proceeded to Phase 2, in which the FMP pilot was rolled out in 16 operators for 12 months.

11 Queensland FMP pilot II (Australia, 2000)

Source: (Friswell and Williamson 2005)

Involved regulators / organisation(s): Small refrigerated transport company; Queensland Transport; Evaluation by NSW Injury risk management research centre, Australia

How fatigue is addressed: FMP intervention was change from 5 to 6 h driving; long, 6h daily break split into 2 x 2 h; 15 min short breaks instead of 30 min. FMP aimed to allow drivers to sleep at more appropriate times of day.

Evaluation outcomes: Basic driving performance probes (start end shift); self-reports to index fatigue; driver diary.Before period and after period 12 d each. Evaluation measures chosen as unintrusive, portable, yield information on functional impairment and driver perceptions of own fatigued state. Results reported elsewhere in this table. Company had already implemented FMP, so strict pre/post design not feasible, but instead 2 measures taken before and after stricter management of FMP. Company small so control not feasible. In after period drivers slept more (total 85 v 70 h), slept longer (6.4 v 5.7 h), and had a greater number of sleeps. A higher percentage of breaks contained sleeps.But no change in performance tasks or subjective rated fatigue. Within each period there were increases in both these measures that would be useful for an organisation.

Description: Preliminary lab study with 39 long distance truck drivers to identify those performance and self-report measures most sensitive to fatigue; and develop a performance standard for those measures linked to an acceptable measure of risk (BAC).Then, 40 drivers studied out on road using the chosen measures (simple reaction time; sustained attention task) under hours of work regulations to give a benchmark against which to assess the FMP. Of these, 14 worked for a small company where an FMP was implemented and evaluated on-road.

12 Western Australia Code of Practice (Australia, 1998)

Source: (Poore and Hartley 1998)

Involved regulators / organisation(s): Western Australia Department of Transport

How fatigue is addressed. Standards and guidelines are given to organisations to help them meet their obligations under health & safety law. Recommends fatigue should be addressed by attending to scheduling, rostering, time working, rest periods, fitness or readiness for duty, health management, workplace conditions, training, policy and procedures, management responsibilities, management of non-compliance, record keeping and documentation. For each standard a variety of control measures are proposed when it is not practicable to adhere to a standard for the reasons suggested above e.g. shared driving, relief driver call-in, amending schedule or roster. The driver training aims to give knowledge on fatigue and health-related issues, awareness about the FMP and what readiness for duty entails. Unsafe fatigue-related incidents that may cause hazard or potential injury should also be documented and followed up as part of the FMP, which should be altered as necessary in accordance with the findings.

Evaluation outcomes / recommendations: The recommended evaluation strategy is based on injury and deaths as outcomes, working hours and practices and costs and benefits to the industry and community.

Description: Western Australia did not have hours of service regulations to underpin their FMP in the same way Queensland did. They therefore decided to use their Occupational Safety & Health Act as a basis for a Code of Practice (CoP). The Act incorporates a Duty of Care. Under this Duty employees have to provide a work place that does not expose employees to hazards; provide education and supervision so that they can work safely; and consult and cooperate with safety and health representatives. Empoyees themselves also have responsibility to ensure their own safety and that of others.The single most important defence to a charge of negligence under this Act is to have written form the practices and procedures that will lead to safe and efficient operations. Where fatigue is concerned, this is an FMP, which should be considered as a component within the risk management programme. The FMP should therefore identify the risk factors and control measures to handle them. These should include open lines of communication between drivers; encouragement of feedback from drivers; inclusion of FMP in human resource procedures; documentation of policies; and record keeping to show that fatigue is tracked and audited. The CoP was developed in conjunction with industry to offer guidance on appropriate standards to be met in order for industry to show they are meeting their duties. It is based on research, gives comprehensive coverage of fatigue causes and the measures that can be used to exclude them from schedules and rosters. Countermeasures are also provided. The CoP says operations must meet certain operating standards (include max continuous work period 5 h; min break time within every 5.5 h; max average work time per rolling 24 h over 14 d; total time not working in 24 h; minimum whole days off in 14 d). Flexibility is given (can exceed 14 h) to allow for delays in traffic; poor rest factilities; need to allow for better night sleep, but active work cannot exceed 14 h two days in a row. At time of writing Code of Practice submitted to the industry for comment. Plans made to field test with transport companies in early 1998 and full implementation in late 1998. Participating companies get discounted insurance premiums.

13 ATA train-the-trainer programme (USA/Canada, 1998)

Source: (Boivin 2000; McCallum, Sanquist et al. 2003)

Involved regulators / organisation(s): American Trucking Association's (ATA) research arm, the ATA Foundation in partnership with the Federal Highway Administration's Office of Motor Carriers (OMC)

How fatigue is addressed: Programme materials (20 minute video, 50 slides; books; pamphlets) based on gaps in driver knowledge about fatigue causes and countermeasures, informed by a large-scale driver survey on the subject. Expert panel also used to inform materials. Hours of sleep and circadian rhythm are main fatigue factors targeted.

Evaluation outcomes: At time of source publication, 3700 trainers had been trained. Training materials well evaluated by a sample of the target audience, though little detail given in sources. Training transfer not evaluated, but plans made to base evaluation on learning outcomes from fatigue courses, trainer evaluation of course effectiveness, changes in driver knowledge about fatigue, and self-reported fatigue behaviour.

Description: A mail survey was sent out bythe American Trucking Association to 25,000 truck drivers in the US and Canada. The response rate was 20 per cent. Survey items assessed driver knowledge and behaviour around alertness and safety, attention and performance, sleep requirements to maintain alertness, sleep deprivation and its effects, sleep apnea, circadian rhythms and their implications, work scheduling, napping, medications and countermeasures to fatigue. The survey showed that drivers underestimated the amount of sleep required to stay alert; 25 per cent thought 5 to 6 h a night was enough. Circadian rhythm effects were not well understood. The train-the-trainer materials tried to do address these and other gaps in driver knowledge. A panel of experts also informed the train-the-trainer session, as part of a larger programme of measures that also included public service announcements, brochures, a video and conference. All materials were made available nationally.

14 Multi-clinic screening of commercial drivers (US, 2000-)

Source: (Leaman and Krueger 2009)

Involved regulators / organisation(s): Intermountain Sleep Disorders Center, Krueger Ergonmics Consultants

How fatigue is addressed: Improve detection and management of sleep disorders.

Evaluation outcomes: Qualitative assessment of employer and driver reactions only given. No evaluation of treatment described, but planned. Report mentions resistance to screening of employees by employers, not employees themselves.

Description: Organisational medical providers were trained in identification of sleep apnea and screening strategy implemented. Steps were taken to promote screening of this group in the community, educate the employers and gain industry support. Treatment of drivers offered (airway device).

15 Operation Healthy Sleep for police officers (USA, 2009)

Source: (Lockley, O'Brien et al. 2009)

Involved regulators / organisation(s): Collaboration between hospital and medical school

How fatigue is addressed: Improve detection and management of sleep disorders.

Evaluation outcomes: Goals to improve officer health, safety and performance assessed by randomized control design. 1126 police officers participated. Half of the districts in a major city police department given FMP, half not. Control and non-control pairs matched prior to randomisation. No results given, but nearly 10 per cent of those officers attending the sleep health presentations were treated.

Description: Sleep health education session given and attendees invited to fill out a survey. Those indicating sleep problems invited for occupational screening for and, if necessary, treatment of sleep apnea.

16 Health education and screening programme involving 117 truck companies (Australia, ca. 2007)

Source: (Howard, Wilson et al. 2009)

Involved regulators / organisation(s): Funded by government workplace and road accident insurers, Worksafe Victoria and the Transport Accident Commission.

How fatigue is addressed: Improve knowledge of, detection and management of sleep disorders.

Evaluation outcomes: 47 per cent of drivers referred to the GP. 19 per cent of drivers had excessive sleepiness, 24 per cent had high risk for sleep apnea and 4 per cent regularly fell asleep while driving. Evaluation of effectiveness based on workplace injury data (includes work in yard and drving). Injury data collected 1 year pre- and 1 year post-FMP (n=800). New lost time injuries fell from 17.1 to 14.2 per cent per year following introduction of programme ($p<.05$). Possible that other factors contributed to fall in injury rate.

Description: Three-year programme involving 12,000 workers. Confidential health screening for sleep disorders, excessive sleepiness, cardiovascular risk factors and alcohol problems. This included collection of self-reports using the Epworth Sleepiness Scale, the Multivariable Apnoea Prediction Index, sleep and work habits, cardiovascular risk factors and alcohol intake. Those with problems given written feedback and advice, and referred to GP for follow-up treatment. Education about fatigue, sleep disorders and cardiovascular risk factors given in the workplace.

17 EasyJet fatigue risk management programme (UK, 2005-)

Source: (Holmes, Stewart et al. 2006; Stewart, Holmes et al. 2006; Stewart 2009; Stewart 2009; Stewart, Holmes et al. 2010)

Involved regulators / organisation(s): easyJet, Clockwork Research consultants, funding from EU.

How fatigue is addressed: Fatigue managed as one element in a system of risk factors using SIRA safety risk management system. Interactions between crew fatigue, rostering practices and human error assessed using a programme that mines data from pre-existing SMS e.g. flight data monitoring; and a model that predicts fatigue from work h and objective measures of sleep. FRMS also informed by crew workshops to identify fatigue factors. Framework for fatigue risk assessment integrated into airline management system so that rosters better account for influences on fatigue. Safety walks, checks, surveys of lifestyles, organisational cultural assessments, feed in together with info from databases on accidents, confidential fatigue reports, flight data monitoring into “system sensory network”, which can trigger in-depth investigation. Competency-based educational and awareness programmes. (Fatigue Awareness & Countermeasures Training, FACT). Performance audit plan. Crew surveyed regularly to monitor changes in contributors to fatigue: commute, delays, early start time, health, home issues, home rest, hotel rest, insufficient rostered rest, late finish, jet lag, roster disruption, long duty day.

Evaluation outcomes: Fatigue risk predictions used often as objective measure in evaluations. Flight deck errors also assessed. Anecdotal evidence that ‘it is possible to improve rostering protocols that minimise operational risk to the airline.’ Over a 12-month period crew rated long duty day as biggest contributor to fatigue. 1800 pilots completed on-line FACT training. Competency tested and kept for records. FRMS operation eg hassle factor of car parking time before duty identified subjectively by crew as a fatigue factor in a workshop. This was tested objectively for fatigue effects by advancing duty time by 1 h and reanalysing schedules with FAID. Percentage duties with high fatigue risk score increased. Thus objective evidence of increased fatigue risk exposure supports staff claims. First UK airline to be granted exemption from Civil Aviation Authorities Flight Time Limitations (In 2005) based on results showing 6 month safety trial of 5/2/5/4 was associated with decrease in fatigue risk (from 1.8 per cent duties classified as high risk fatigue to 0.7 per cent) and flight deck error (from mean error rate of 5.2 per sector to 2.6 per sector). Pilots Association approved change. 91 per cent said they felt less tired on the new roster. EasyJet reports a substantial reduction in its accident insurance premium as a result of its FRMS.

Description: Those affected by rosters considered in combination with operational measures. Roster evaluation Group balances safety criteria form fatigue risk assessments against operational (commercial) objectives. Fatigue risk management highly integrated part of company's Safety Management System.

Mechanism for crew to report on fatigue in which crew report on self and colleagues about fatigue. Requires openness about fatigue. Stresses organisational learning, continuous, re-iterative approach to risk management, e.g. training module continuously updated in response to feedback. Procedures for monitoring fatigue levels; fatigue incidents; taking interventions based on monitoring; and evaluating those interventions.

18 Train driver roster redesign (Multinational study, ca.2007)

Source: (McColgan and Nash 2009)

Involved regulators / organisation(s): Not known.

How fatigue is addressed: Those affected by rosters.

Evaluation outcomes: Fatigue risk index reduced after roster redesign, while maintaining operational considerations.

Description: Roster analysis and redesign involving 1,223 train drivers, to account for fatigue. Roster evalation and redesign by 1) Roster review by experts and consideration of driver and manager interviews; 2) Biomathematical modelling based on Fatigue Index Risk Module.

19 North American FMP for truck drivers (USA / Canada, mid-late 2000s)

Source: (Bagdanov 2005; Moscovitch, Reimer et al. 2005; Smiley, Smahel et al. 2009)

Involved regulators / organisation(s): Original study by Transport Canada / FMCSA (regulators) involving 87 drivers from 3 companies: Robert Transport (Québec), ECL Group (Alberta), JB Hunt Transport (CA). Sponsors: FMCSA (US DOT); Transport Canada; Alberta Transportation. Later taken on and developed in Alberta by Vehicle Safety and Carrier Services and Alberta Infrastructure and Transportation in association with the Canadian Sleep Institute where the study organisations were Greyhound Buses; Canadian Freightways; Grimshaw Trucking; and Mantei's Transport.

How fatigue is addressed: Multi-level education through train-the-trainer. Four modules: core, trip planning, wellness and lifestyle; sleep and sleep disorders. Educational quizzes and bi-monthly newsletter. Sleep monitoring and treatment programme. Attempts to improve knowledge and awareness of fatigue issues by drivers, dispatchers and families. Screening and treatment of drivers for sleep disorders.

Evaluation outcomes: Original study: Measures collected on driver fatigue, performance, sleep duration, mood. Pre and post-FMP data (10 d each; n = 77) collected from drivers on psychomotor vigilance (using hand-held computers): sleep timing and quality (driver actigraphs), start and end of shift data on mood. Company performance (e.g. crashes, absenteeism), policies, practices also recorded. **Results:** Drivers slept longer and more efficiently during the post-FMP than pre-FMP condition on duty days, according to actigraph data. Self-reports also showed drivers were aware they slept longer and better than before. Scores on the psychomotor task improved during the rest days for severely fatigued drivers. Drivers reported less close calls or nodding off after than before the FMP. Changes in other measures are not reported. Problems: Found initial 4 x 90 min training sessions too time consuming for trainees, the time had to be reduced. Problem getting drivers together. Trainers had problem with subject matter. Drivers treated with sleep apnea continued to drive before being treated creating an ethical dilemma for the organisation. Adherence to sleep apnea treatment by drivers was low. Insurers become reluctant to get involved in apnea treatment. Evaluation of later Alberta study by Moscovitch et al. suffers from lack of power. Pre- and post-subjective (questionnaire and daily log) and objective (actigraph for sleep; PVT for fatigue) measures; with intervention and rollout over 12 months inbetween. Only 10 drivers in post-measure sample, so significance not reported. However, both subjective and objective on- and off-duty ratings of sleep amount increased from pre- to post-measure. Notably, the increase in sleep duration for a treated apnea group (n=7) was from 236 to 408 minutes on average. The number of fatigue lapses measured by PVT decreased by 67 per cent.

Description: Customised multiphase programme with educational, operational and clinical parts. Educational sessions offered to managers, drivers, dispatchers and their families. Participating drivers screened and treated for sleep disorders. Education designed to inform truckers on when they should take the decision to pull over.

20 CANALERT FMP (Canada, 1995-8)

Source: (Moore-Ede 1996; FRA 1998; McCallum, Sanquist et al. 2003)

Involved regulators / organisation(s): Transport Canada initiated an employer-employee partnership called CANALERT in 1995. It comprised Canadian National, Canadian Pacific Railroad, VIA Rail, Brotherhood of Locomotive Engineers and Circadian Technologies.

How fatigue is addressed: Improve predictability of schedules for drivers so that they can better plan their sleep; improve sleeping environment; implement napping policy to improve on-duty alertness; train employees and families on how lifestyle affects fatigue on the job so drivers can better exploit sleep opportunities.

Evaluation outcomes: Programme restricted to engineers because of union reluctance. Evaluation questions. Did each countermeasure work and how much?

Did combined programme work? 1 mo baseline testing; 3 mo intervention; 1 mo post-testing. (n= 16 larks; 12 owls, 12 cats). Locomotive engineers kept sleep-wake-work logs; and were wired up to an EEG recorder on randomly selected trips, and sleeps in sidings. Stress recorded using heart rate variability measurement. Organisational measures: absenteeism. Baseline results showed the routes on which drivers were most stressed and fatigued, and where improvements might be limited or not. 80 per cent Participants rated time pools as having positive effect on fatigue and social life. Clear reductions in absenteeism, in one division from 8.1 to 3.2 per cent. Importantly, the reduction in absenteeism led to more predictable crew management for schedulers, and in turn more predictable rosters. Subjective ratings of alertness and sleep interindividual variation prevented statistical differences in microsleep episodes and EEG ratings. Sleep efficiency increased from 88 to 94 per cent in bunkhouses after changes to work environment in a test bunkhouse; no change in control house. Reports of nodding off on runs decreased from 38 to 30 per cent in one location and 23 to 16 per cent in another. Participants also reported improvements in gastrointestinal health as result of lifestyle programme.

Description: Root causes of locomotive engineer fatigue identified and countermeasures developed. Included circadian time pools (drivers scheduled as 'larks', 'owls', or 'cats'), more predictable work patterns, recuperative napping, better sleeping accommodation; headsets to decrease noise and stream music; 4 h lifestyle-management training programme for employees and families. In 1997-8 an enroute napping policy was described giving 20 min sleep opportunities and empowered drivers to take demand and opportunity naps.

21 Study to inform planned FRMS for French regional airlines (France, 2009)

Source: (Mollard, Debouck et al. 2009)

Involved regulators / organisation(s): French airline regulator, Direction générale de l'Aviation (DGAC)

How fatigue is addressed: Improved scheduling by biomathematical modelling.

Evaluation outcomes: Sick leave in addition to predictors generated by model.

Description: The source describes a study launched to implement FRMS for French regional airlines. Uses biomathematical prediction of fatigue based on fatigue risk index and sleep wake predictor. Early stage outline of future FRMS achieved only at time of publication.

22 "SAFE-T" Alertness Management training for Ford truck drivers (Germany, ca. 2003)

Source: (Jettinghoff, Staren et al. 2005) (Roenicke, ten Thoren et al. 2005)

Involved regulators / organisation(s): The AMCO (Network of Competence, Fatigue in Transportation) network is a joint initiative of several national bodies with an interest in road safety. Most prominent are the German Aerospace Centre (DLR); the German Accident Prevention and Insurance Association; and the truck fleet of Ford AG, Cologne.

How fatigue is addressed: Knowledge and awareness of fatigue given to drivers; sleep disorders monitored and treated; scheduling to better account for sleep history and circadian rhythms.

Evaluation outcomes: Outcome measures were self-reported attitudes and knowledge of drivers from pre- and post-training questionnaires. The results show that the Alertness Management Training improved the drivers' knowledge in basic principles of sleep, fatigue and shift work. Furthermore, changes in their attitudes were observed. The changes were statistically significant.

Description: This programme is based on the premise that driving hours of lorry drivers are too inflexible because they fail to take individual differences into account. The training in particular aims at increasing road safety by helping drivers to deal with fatigue themselves; this includes finding out causes of fatigue while driving and working out suitable strategies to prevent the fatigue identified. "SAFE-T" stands for Self-responsibility, Advice, Feedback, Evaluation und Training. Programmes were begun in several organisations to train managers and drivers. The training was based on training used previously in the USA; it aims to give drivers more insight into their own particular biorhythms, and provide strategies to enable them to recognise their own symptoms of tiredness. Software has been developed as part of the project to predict a person's rhythm; at the time of writing this is being tested by 45 drivers. The software accounts for lifestyle aspects such as eating, drinking, sleeping habits, and exercise. The latest aspects of the training programme attempt to involve the planner. US research on the training programme showed improvement in behaviour and reports of reduced fatigue among drivers. The software is to be sold to companies with the idea that it will eventually make their drivers better. The programme also includes medical screening for sleep apnea among drivers. The drivers also kept a sleep and fatigue diary.

23 Scheduler management of driver fatigue risk score (USA, 2001-2)

Source: (Moore-Ede, Heitmann et al. 2004)

Involved regulators / organisation(s): Circadian Technologies Ltd consultants; intervention in an organisation with fleet of 500 trucks.

How fatigue is addressed: Dispatchers and managers were held accountable for minimizing driver circadian-based fatigue risk scores.

Evaluation outcomes: The total number of truck accidents dropped 23 per cent from an average rate of 2.3 per million miles for the 3 y period prior to the intervention year. Average cost per accident dropped by 66 per cent. Severe accident rate dropped 55 per cent. The cost of loss of attention accidents dropped by 81 per cent.

Description: Risk-informed performance-based (RIPB) safety programme in fleet of 500 trucks. The Circadian Alertness Simulator (CAS) was developed as a practical tool for assessing the risk of diminished alertness at work. Applications of CAS include assessment of operational fatigue risk, work schedule optimization, and fatigue-related accident investigation. Based on the documented work schedules of employees, sleep and alertness patterns are estimated and a cumulative fatigue score is calculated. The risk assessment algorithms are based on physiological sleep/wake principles including homeostatic and circadian processes. The free parameters of the algorithms were optimized using over 10,000 d of sleep and alertness data sets collected from transportation workers performing their regular jobs. The validity and applicability of the CAS fatigue score was then tested using work/rest and accident data from three trucking operations. Heavy truck drivers involved in DOT-recordable or high-cost accidents were found to have significantly higher CAS fatigue risk scores than accident-free drivers. Implementing a risk-informed, performance-based safety programme in a 500 power-unit trucking fleet, where dispatchers and managers were held accountable for minimizing driver CAS fatigue risk scores, significantly reduced the frequency and severity of truck accidents. Further examination of CAS risk assessment validity using scenarios provided in a fatigue modeling workshop indicated that the CAS Model also performed well in estimating alertness with a real-world transportation scenario of railroad locomotive engineer work/ rest patterns.

24 Dupre driver management of own fatigue risk score (USA, 2005)

Source: (Moore-Ede, Heitmann et al. 2005; Moore-Ede 2010)

Involved regulators / organisation(s): 500-unit US truck company -- Dupre Transport (gasoline delivery), Lafeyette, LA, with Circadian Technologies, USA, as consultants. Dupre's insurance company initiated initial assessment finding elevated CAS scores

How fatigue is addressed: Increase awareness of driver's own fatigue by personalised driver feedback on fatigue risk (CAS) score; this was coupled with increasing driver empowerment by giving them responsibility for adjusting own duty-rest hours to minimize fatigue risk; and coaching on how to reduce scores by altering timing of duty and rest hours. There was also manager and driver sleep management and alertness training.

Evaluation outcomes: Outcome measures: accident rate associated with driver lapses of attention (Rollovers, Rear-End, Lane Change and Intersection Accidents); Fatigue risk scores; Staff turnover rates. Compared to baseline years 1999, 2000 & 2001 with a traditional safety programme accident rate was 1.29 per million miles, and fell during the RIPB programme to 0.9 in 2002, to 0.8 in 2003 and to 0.5 in 2004. Personal injuries rate also fell from 4.89 injuries per 200,000 hours worked in the baseline years 1999 to 2001 to 1.5 in 2002 and to 1.0 in 2003 and 1.1 in 2004. Over the three years of FMP fatigue risk score progressively decreased from 40 to 25. The number of drivers with Fatigue Risk Scores above 60 fell from 21 to 2. The baseline average driver turnover rate was 107 per cent per annum. With RIPB it fell to 79 per cent, 87 per cent and 69 per cent over the next three years. Note: this is not an independent evaluation.

Description: Intervention carried out on 125 irregular-route long-haul truckload-drivers on multiple day trips with sleeper berths provided. Drivers given their individual fatigue scores monthly for three years, and held accountable by their managers at to adjust their duty-rest hours to minimize fatigue scores in an RIPB programme. The scores were based on predictions generated by the Circadian Alertness Simulator (CAS), a biomathematical model using input from audited duty-rest logs. Authors conclude that truckload drivers provided with fatigue risk scores can modify their duty-rest patterns to minimize fatigue and reduce accidents. Note: Dupre won awards for safety management before the intervention.

25 Accounting for fatigue risk in train driver schedules (Australia, 2000s)

Source: (Dawson, Noy et al. 2010)

Involved regulators / organisation(s): Australian rail industry.

How fatigue is addressed: Objective assessment and improvement of train driver schedules based on fatigue risk scores they predict.

Evaluation outcomes: Anecdotal. Significant reduction in long shift sequences (up to 12 consecutive 12 h shifts) in exchange for longer periods of time away from work (4-6 d). Resulted in increase in overall 'sleep opportunity'. Drawback: prescriptive use of a non-prescriptive tool due to culture in organisation e.g. shifts one point below threshold considered acceptable

Description: Fatigue Audit InterDyne (FAID) software used by the rail industry to assess schedules on the basis of fatigue risk scores. Upper limit of acceptability for shifts set at FAID score 80-90.

26 Washington State Ferry employer-employee partnership to manage fatigue (USA, 2001)

Source: (McCallum, Sanquist et al. 2003)

Involved regulators / organisation(s): Washington State Ferry in association with US Coast Guard research team.

How fatigue is addressed: Training to improve knowledge of fatigue and its causes; employee representatives identified as "champions".

Evaluation outcomes: Anecdotal. Group still met in 2003, both employers and employees "fully committed". Study found that crew were initially reluctant to change schedules, because they had become used to their routine.

Description: Crew Endurance Working Group formed including management and employee representatives. Aim is to study and improve fatigue-related conditions. As a result, information provided to fleet personnel on training and education about fatigue. Employee representatives have become "crew endurance coaches".

27 BA FMP for airline crew (UK, ca. 2000)

Source: (McCallum, Sanquist et al. 2003)

Involved regulators / organisation(s): British Airways

How fatigue is addressed: Improve operator knowledge of fatigue and its causes; Alertness Management Manual and trip-specific advice cards provided.

Evaluation outcomes: Training material evaluation (manual and card usability, presentation). Non-compulsory survey of crew members showed there were high levels of satisfaction with the manual, and even experienced crew found trip-specific information valuable.

Description: No other details.

28 Burlington Northern Santa Fe FMP for rail crew (1998-)

a. Change in rail crew schedule

Source: (McCallum, Sanquist et al. 2003)

Involved regulators / organisation(s): Burlington Northern Santa Fe, railroad company.

How fatigue is addressed: Mainly by change in schedule to better account for fatigue.

Evaluation outcomes: Pre- and post-intervention measurements of self-reports and performance. Moderate approval ratings by employees on the change in lifestyle. Reduction in subjective ratings of fatigue but not in performance.

Description: New 10-days-on 5-days-off scheduling agreement.

b. 'Napping'

Source: (Hartley, Buxton et al. 2008)

Involved regulators / organisation(s): Burlington Northern Santa Fe railroad company

How fatigue is addressed: Training to improve knowledge of fatigue countermeasures, sleep environments, napping opportunities.

Evaluation outcomes: None given.

Description: In coordination with training in fatigue countermeasures, on- and off-property rest rooms, scheduled days off, a trial programme on napping was introduced based on NASA Ames research. Employees told that napping is encouraged where needed, and that napping time is on-duty time. Employee questions about the new guidance were included in the final guidance.

c. Sleep awareness through individualised actigraph feedback

Source: (Sherry and Philbrick 2004)

Involved regulators / organisation(s): Burlington Northern Santa Fe railroad company; independent evaluation by University of Denver

How fatigue is addressed: Use actigraph feedback to increase awareness about own sleep, to promote increased sleep

Evaluation outcomes: Pre- and post-testing using actigraphs, various self reports and the sleep logs. Readings from feedback actigraph worn for 30d (n=11) and compared with non-feedback actigraph (n=10). No significant differences on stress, fatigue, job satisfaction, anxiety, quality of life between two groups, but the power severly limited. However, those receiving feedback said the actigraph helped them monitor their fatigue levels.

Description: Participants wore actigraph 24 h a day and completed a daily sleep log, for 30d. Test participants were then given feedback on their work/rest habits, and a discussion about their habits, before being asked to wear the device another 30 d. Control participants given no feedback

29 Western Australia guidance on napping policy (Australia, 2008)

Source: (Hartley, Buxton et al. 2008)

Involved regulators / organisation(s): Murdoch University and Krueger Ergonomics Consultants for Western Australian Government

How fatigue is addressed: Guidance for organisations to draw up a policy that empowers napping as a fatigue countermeasure.

Evaluation outcomes: None known.

Description: A guide that transport operators can use to develop a napping policy to help satisfy Duty of Care provision of the Occupational Safety & Health legislation of Australia. Guidelines and policy can only succeed given right organisational support measures. Preventative and operational nap guidelines should be introduced against a background of an organisational commitment to safe work practices, commitment to employee health, and compliance with the Duty of Care. Drivers should be trained about sleep and the effects of fatigue, and the need for napping. Good napping conditions should be ensured by the employer. Health screening recommended as way to give feedback on need for or effect of napping.

30 Napping pilot study in air crews (USA, 2000s)

Source: (Hartley, Buxton et al. 2008)

Involved regulators / organisation(s): NASA/Federal Aviation Authority

How fatigue is addressed: Napping enabled as an in-flight measure to counter fatigue

Evaluation outcomes: Members of three-person flight crews randomly assigned to control group (no naps) or experimental group (40-minute in flight sleep opportunity). Behavioural alertness measured. Crew actually slept 25 minutes on average in the 40 minute window. Alertness enhanced, especially towards end of flight.

Description: Napping enabled in long haul aircrews.

31 Research evaluation of demanding FMP schedule for truck drivers (Australia, late 1990s)

Source: (Williamson, Feyer et al. 2000)

Involved regulators / organisation(s): Three organisations participated: one on the FMP and two on the regulatory schedule.

How fatigue is addressed: Allow increased flexibility in scheduling.

Evaluation outcomes: Palm-top reaction time and monitoring tasks were used to assess driver fatigue on road. Rest prescribed in the regulated regime was sufficient to manage fatigue, but if taken beyond limits the authors claim that safety is likely to be compromised. Results for the demanding FMP schedule included that driving up to 16 h can be done without compromising performance, provided that drivers are rested beforehand. *i.e.* such long driving sessions are ok if balanced by long rest periods. Being as 6 h rest periods were followed, the particular 'FMP schedule' followed here was assessed as detrimental to performance.

Description: Max 14 h in a 24 h period (normal legislation) increased to a possible 16 h in a 24 h period with 6 h intervening breaks under the FMP (overall schedule covered 60 h). This research project aimed to evaluate the effect of following such a schedule; and the effect of the original legislation on fatigue.

32 TCRP Toolbox for transit operator fatigue (USA, 2002)

Source: (Gertler, Popkin et al. 2002)

Involved regulators / organisation(s): Prepared by Foster-Miller Inc, Rantsu Consulting and KKO Assoc for the Transportation Research Board – National Research Council, USA

How fatigue is addressed: Manual and companion CD made available as guidance for organisations; based on literature review identifying *proven* strategies for preventing, detecting and minimising the performance effects of fatigue.

Recommends fatigue is addressed by an FMP, and outlines organisational prerequisites necessary for an FMP, stressing top-down implementation, and the importance of organisational change processes. The Toolbox provides a collection of tools and strategies that can be selected and tailored according to the cultural and operational characteristics of the transport company. Most tools to be accompanied by training. Tool categories: managing personal habits and behaviours; reporting for duty and managing service delivery; analysing and creating runs; assigning personnel to cover temporary vacancies; designing facilities and equipment; recruiting and hiring new operators; investigating accidents

Evaluation outcomes: Recommends taking pre- and post-FMP measures on overtime charges per operator; absenteeism; injuries / h worked; accidents / 100,000 mi; vehicle maintenance costs; disciplines for safety violations; accidents/incidents where fatigue was a causal factor. Also recommends assessment of driver alertness; sleep debt index; and recording of anecdotal information.

However, no known evaluation by an organisation that has implemented and evaluated an FMP using the Toolbox.

Description: The Transit Cooperative Research Programme is the principal means by which the transport industry in the US 'can develop innovative near-term solutions to meet demands placed on it'. It provides a forum whereby transit agencies can cooperatively address common operative problems. The TCRP produced in 2002 a manual or Toolbox to document principles, techniques and strategies used in the development of FMPs by managers, safety officials, medical personnel, risk managers, HR personnel and policymakers. The manual is designed as a collection of tools and strategies that can be selected and tailored according to the cultural and operational characteristics of the transport company. The manual has chapters on Understanding fatigue (knowledge and awareness of research on the problem); How to develop and implement an FMP; Tools you can use. The Tools are also detailed on the accompanying CD, which also includes material that can be used when developing and publicising the FMP eg posters to promote specific tools, articles and brochures on fatigue, excerpt for an employee newsletter. The **tools** are split into seven categories: managing personal habits and behaviours (tools for drivers to self-assess sleep debt, sleep-log to monitor progress towards better sleep, caffeine-use advice, effective nap-use, drugs that cause fatigue, info to help those with a sleep disorder; exercise, relaxation techniques;making your family part of the strategy; and food advice); reporting for duty and managing service delivery (recognising a fatigued driver; fitness-for-duty; coaching a fatigued employee); analysing and creating runs (schedule design and analysis); assigning personnel to cover temporary vacancies; designing facilities and equipment; recruiting and hiring new operators; investigating accidents. The manual states that most of the tools will only be effective of implemented in conjunction with a fatigue training programme that provides instructions about them. The chapter outlining **organisational prerequisites** precedes the tools. To benefit the organisation optimally, the target of the FMP should be all employees, not just drivers. The foundation process comprises securing and maintaining management commitment; policy and programme development; communication and training; managing fatigue and alertness; monitoring, reviewing and modifying. The manual describes for each of these stages tools that fit. Thus, Chapter 1 'why fatigue is important' and Appendix C 'success stories' fits into the first stage and so on. In this way a comprehensive but pack of information and materials is provided to the manager, who is clearly informed about how to use it.

33 US Coastguard Crew Endurance Management System (USA, 2000s)

Source: (Gertler, Popkin et al. 2002)

Involved regulators / organisation(s): US Coastguard

How fatigue is addressed: Employer-employee partnership to develop plan, which includes training to improve knowledge of fatigue issue; consideration of role of working environment; and scheduling for optimal alertness.

Evaluation outcomes: None known.

Description: Crew Endurance Management System, derived from similar system developed by Army Safety Center in early 1990s. Process is to evaluate current policies; form a Crew Endurance Working Group with representatives of each group on vessel; working group meets to develop a crew endurance plan; education programme for crew. CEMS considers company mission, equipment limitations, environmental factors against the crew's physiological and psychological limitations, and the crew rest and work hours policies. A primary aim is to maximise alertness by optimising duty hours.

34 Ocean Shipholdings' Schedule Change (Multinational, 1998-9)

Source: (Gertler, Popkin et al. 2002)

Involved regulators / organisation(s): Ocean Shipholdings

How fatigue is addressed: Old schedule changed so that 12 h sleep opportunity instead of 8 h, in exchange for extended working period.

Evaluation outcomes: Positive feedback from crew on how they feel. Decrease in number of near misses attributed to fatigue. Statutory work and rest requirements met.

Description: Schedule change to allow longer block of time for sleeping, after successful German research study. Rolled out slowly across organisation, so other crews could see that it was successful.

35 Ingram Barge FMP (USA, 2000)

Source: (Gertler, Popkin et al. 2002)

Involved regulators / organisation(s): Ingram Barge Co., USA on consultation with US Coast Guard R&D Center.

How fatigue is addressed: Training; participative schedule re-design to afford greater sleep opportunity; improving rest facilities; exercise and caffeine management to improve sleep.

Evaluation outcomes: Only some groups kept system, the others reverting to the old schedule. Crew members on the new schedule were two to three times more likely to get over 5 h sleep.

Description: 1.5 d workshop on fatigue and alertness and consult crew on designing plan for vessel by helping them analyse work schedule and cycle. As a result crew decided to change from 6 h on/6off/6on/6off to 7h on/7off/5on/5off. Crew also agreed / suggested maximising rest before work, limiting alcohol, avoiding overeating, managing caffeine and staying fit. Sleep conditions on vessels also improved. Tested on 1 vessel followed by wider roll-out.

36 NASA training and train-the-trainer modules on alertness management (USA, 1993-)

Source: (Rosekind, Neri et al. 1998; Gertler, Popkin et al. 2002)

Involved regulators / organisation(s): NASA Fatigue Countermeasure Programme (formerly NASA Ames Research Center); module used by many organisations e.g. Delta Airlines; BP Oil NZ Ltd.

How fatigue is addressed: Training module designed to disseminate results of this research. It aims to explain current knowledge, demonstrate how knowledge can be used to improve sleep, performance and alertness, and offer fatigue management strategies.

Evaluation outcomes: In 2002 it was estimated that 116,000 flight crew personnel had received the training. A 1998 course participant follow-up survey found that over half course participants said that the module had initiated positive changes related to fatigue in their organisation.

Description: Training module from influential research programme that aimed to map fatigue problems in air transport, and validate countermeasures. Designed for long-haul crews, but web-based module for other crews planned. Delta Airlines one of many using the module as the core of its FMP. Driven by corporate management, Delta's FMP began in 2000, and it supplements the NASA module with a class for management overseeing flight operations.

37 Continental Airlines FMP (USA, 2005-)

Source: (Gunther 2008)

Involved regulators / organisation(s): Continental Airlines

How fatigue is addressed: Set company duty time limits; develop rosters using biomathematical modelling; learn continuously by responding to fatigue data (diaries, actigraphs, questionnaires); inform policy development.

Evaluation outcomes: Not known

Description: A Fatigue Risk Management Team within flight operations has multi-level, multidisciplinary representation, reports to the corporate Safety Review Board and is seen as integral to Safety Systems Management approach in the organisation. The FRMT meets at least 4 times a year; its aim is to develop and review fatigue mitigation strategies. FMP thinking informed by five-tier defense model (Dawson and McCulloch 2005). Level 1. Does roster allow enough sleep opportunity? Use computer-based rostering and predictive modelling (SAFTE/FAST). Level 2. Do employees take advantage of sleep opportunity? Employee surveys, actigraphs. Level 3. In the workplace do they maintain alertness and performance? Self-reports, co-worker reports, palm-top Psychomotor Vigilance Task, when needed, refer for assessment for sleep disorders. Level 4. Are there errors or near misses? Level 5. Are there incidents and accidents?

38 Air New Zealand FRM (New Zealand, 2000s)

Source: (Powell and Fallow 2008; Powell 2009)

Involved regulators / organisation(s): Air New Zealand

How fatigue is addressed: Data on fatigue in crew being built up to be fed back through regular fatigue reports, operational studies and a top-of-descent survey.

External review and audit seen as important. In 2008 models being tested, with plans to integrate into rostering software.

Evaluation outcomes: Not known.

Description: Air NZ focuses on maintaining a 'just culture' with openness and feedback is essential to the success of fatigue management approach within a Safety Management Systems framework. Management and unions work together from the outset establishing agreed processes. Management commitment to act where required.

39 American Airlines FMP (USA, 2000s)

Source: (Gertler, Popkin et al. 2002)

Involved regulators / organisation(s): American Airlines

How fatigue is addressed: Knowledge and awareness. Limited rescheduling.

Evaluation outcomes: Anecdotal reports that a change in culture has been achieved such that now staff feel it is ok to report that they are too tired to work.

Description: Fatigue training programme or film; fatigue hotline giving advice on a fatigue issue; internet articles and info about fatigue.

40 Greyhound FMP (USA, ca. 2000)

Source: (Gertler, Popkin et al. 2002)

Involved regulators / organisation(s): Greyhound Bus

How fatigue is addressed: Fatigue knowledge and awareness; better nutrition; scheduling to improve predictability, sleep opportunities and minimise inverted work cycles.

Evaluation outcomes: None known.

Description: New employees are trained on fatigue management and nutrition, with a focus on how off-duty activities can influence fatigue. Uses FMCSA's 'Motorcoach Operator Fatigue' video. Scheduling must assure on-duty time not greater than 9 h, and provide at least 9 h sleep opportunity. Inverted work cycles are minimised. Drivers Schedules are predictable for the driver and drivers can call in fatigued without penalty.

41 Canadian Marine Pilots FMP (Canada, 2007)

Source: (Rhodes and Gil 2002; Unknown 2007)

Involved regulators / organisation(s): Transport Canada's Marine Safety Directorate; Transportation Development Centre (TDC) of Transport Canada; Canadian pilotage authorities; Canadian ship owners; Canadian marine pilots

How fatigue is addressed: Sleep and fatigue awareness training for pilots and management; scheduling to account for fatigue using FAID software; support resources, process and responsibilities for FMP implementation; FMP evaluation.

Evaluation outcomes: Not known

Description: Literature review and survey of pilots forms the basis of FMP guide; training materials for 6 h workshop; scheduling guidelines; programme monitoring and evaluation guidelines. Training materials are FMP guide for operators; slides and trainers handbook; set of Powerpoint slides. Evaluate current coping strategies and recommends additional ones (eg reduce schedule uncertainty; night assignment length; rest strategies).

42 RailCorp FMP (Australia, 2005)

Source: (Railcorp 2005)

Involved regulators / organisation(s): RailCorp

How fatigue is addressed: Knowledge and awareness of fatigue; how to identify fatigue in self and others; coping strategies; Advice on shiftwork from Employee Assistance Programme; Roster design must achieve predicted fatigue below a threshold; Fatigue-related incidents to be investigated;

Evaluation outcomes: Fatigue management index measured by FAID used to assess rosters. No mention of evaluation as way to inform iterative evolvement of measures and measure success of programme.

Description: Managers clearly held responsible for FMP; employees clearly consulted on roster design.

43 Road transport company FMP (Australia, 2000s)

Source: (Holmes, Baker et al. 2006)

Involved regulators / organisation(s): Interstate road transport company with 200 drivers.

How fatigue is addressed: FMP within SMS framework; Training to management and employees on how to manage fatigue at work and home. Introduce a sleep contract, with information about it to employees.

Evaluation outcomes: Qualitative interviews with company managers. Reported fatigue incidents recorded in database, which is evaluated periodically. Reports that company accident statistics show reduction in fatigue-related incidents. 4 drivers report fatigue in last six months. According to interviews sleep contracts should include statements of how tired is too tired, and how this should be identified, and the process that should be activated when fatigue is reported

Description: Sleep contract contains standards on how much sleep employee must obtain prior to work; statement of employee responsibility to inform management when standards breached, or they experience fatigue; in which case management system activated and no sanctions taken.

44 Pilot study for sleep apnea management (USA, 2005)

Source: (Berka, Westbrook et al. 2005)

Involved regulators / organisation(s): 56 service centre managers, most ex-long-haul drivers. Research by Advanced Brain Monitoring Inc., CA

How fatigue is addressed: Sleep disorder monitoring and treatment

Evaluation outcomes: 52 per cent identified from questionnaire as high-risk for sleep apnea. Of these, ca.67 per cent agreed to follow-up home study. Given feedback and education. No evaluation of the effects of intervention.

Description: Describes protocol for use of Apnea Risk Evaluation System (ARES) questionnaire to identify those at high-risk for sleep apnea; followed by overnight monitoring and education.

45 FMP Toolbox for aviation maintenance and operator personnel (Canada, 2005)

Source: (Booth-Bourdeau, Marcil et al. 2005)

Involved regulators / organisation(s): Civil Aviation Directorate, Transport Canada

How fatigue is addressed: Three main activities described: i. Policy development; ii. Training and education programmes for all; iii. Audit systems for determining fatigue levels in a company i.e. an organisation should begin by delineating policy and ensuring prerequisites in place for use of this toolbox, which is Training material a) for employees on causes/consequences of fatigue, napping, food, water, caffeine, alcohol, nicotine, wellbeing, exercise, drugs, family and social life, commuting, work design and jet lag. b) for management on FRMS, legal obligations, need for training, fatigue control measures detailed at five defence levels.

Evaluation outcomes: 12 month implementation trial planned.Will look pre- vs post-FMP absenteeism, error incidents, training knowledge, cost/benefits, degree to which toolbox needed to be tailored to the specific company, subjective opinion of implentation process and of toolkit efficacy.

Description: Inspired by five defence model (Dawson and McCulloch 2005); uses FAID biomathematical modelling to give fatigue risk scores. **Policy development** should aim to achieve pervasive principles and norms; organisational cultural change; visible management commitment; get guidance in devising new systems. The toolbox gives example of policy rather than a template, which it says would be too restrictive. These give background information, outline accountability, allocation of resources, programme coordinator establishment, guidelines and procedures for training and controlling fatigue, incident and accident reporting procedures. **Training and education** is seen as essential for change. It warns against mere ‘awareness-raising’ training, which is poor for knowledge retention, stressing that the training should be competency-based to allow knowledge acquisition and FM skill development. The training component of the FM toolbox contains 3 booklets: 1.Fatigue management strategies for employees, which focuses on reducing fatigue and its effects at the individual level (assessment and certification procedure included). 2. Fatigue for the manager; 3. Fatigue for new employees**. Fatigue audit** tools comprose FAID biomathematical model software.

46 AC Barge Crew Endurance Management (USA, 2004-7)

Source: (Dougherty 2005)

Involved regulators / organisation(s): American Commercial Barge Line Derived from US Coast Guards Crew Endurance Management Systems

How fatigue is addressed: Light management; information on quantity and quality of sleep required provided to crew.

Evaluation outcomes: Anecdotal lessons: Casual management support is insufficient. Educate *all* managers about management system. Reckon with resistance to change when getting employee buy-in. Counter by giving clear reasons for change. Develop in-house experts or 'coaches' as accessible consultants.

Description: Programme rolled out based on 2000 pilot.

47 US Coastguard Crew Endurance Management Systems demonstration project (USA, 2000-5)

Source: (Emond, Stevens et al. 2005)

Involved regulators / organisation(s): 43 vessels from several companies involved in pilot: American Commercial Barge Line; Blessey Marine Service; Moran Towing Corp.; Kirby Corp; Penn Maritime; Marathon Ashland Petroleum; American Electric Power; Memco Barge Line Inc.

How fatigue is addressed: Process and system components described for endurance management.

Evaluation outcomes: Baseline measures Jan 2005, post June 2005.

Not enough accidents to evaluate FMP effect, therefore 'relative risk that fatigue might cause a casualty' measured. This measure is part of the CEMS risk assessment process. This evaluates 15 risk factors in 5 categories: sleep, schedule/circadian rhythm; physical stressors; environmental stressors; personal stressors. At time of report, no post-measure made. As of 2005 60 crew endurance experts had been trained across 23 companies.

Description: Process: 1. Set up working group; 2. Analyse status quo; 3. Develop endurance plan; 4. Implement; 5. Evaluate results, then feedback to 2. System components are education (multi-media information [web-site, pamphlets, Management manual] and strategy for training for Crew Endurance Coaches); environmental changes; light management; coach on vessel; and schedule changes.

48 Enform employer guide to FMP design and implementation (Canada, 2003, revised 2007)

Source: (Enform 2007)

Involved regulators / organisation(s): Enform prepared report for various oil and gas operations in Canada e.g. Conocco Phillips, Alberta Transportation, BP Canada

How fatigue is addressed: Guidance on FMP implementation.

Evaluation outcomes: It is not know which organisations have actually used this programme, or whether there are evaluations available.

Description: Advice on optimal scheduling and shiftwork patterns, work task type and length, work environment and fit with health and safety culture. To implement a programme i. FMP champion presents case to senior management; information on fatigue collected; stakeholders engaged and FMP team formed with all employee groups represented; FMP aims clarified; decide on measures; assess and document causes and current fatigue (baseline for evaluation); implement FMP; build competency through needs and analysis and training cycle at all levels; evaluate programme.

49 McCafferty coach driver FMP (Australia, 2000-2)

Source: (Machin 2001; Machin 2003)

Involved regulators / organisation(s): McCafferty's Express Coaches, with evaluation by University of Queensland

How fatigue is addressed: At the core of the FMP is a basis of providing coping strategies according to the transactional model of driver stress. Driver consult to create participative training exercises.

Evaluation outcomes: Training evaluation measures. Ratings of training, post-training self-efficacy and intentions all positive. Drivers who thought the training was most realistic reported better training outcomes. But no evaluation of business effects.

Description: Stage 1. Driver survey to assess fatigue and stress; emotional and physical wellbeing 2. Use survey results to develop training exercises (interactive training in which drivers make judgements about how best to cope in different fatigue situations) 3. Evaluation of effectiveness of this training. Training situations were developed in a workshop involving coach driver supervisors. For each situation, the workshop identified effective and ineffective responses, strategies and coping styles. Drivers were then assessed for coping style before being given four scenarios developed in the workshop. Drivers rated how they would think, feel and behave in response to each scenario, and rate the workshop 'best responses' for effectiveness. They were then asked to predict scenarios they might actually be faced with in the coming weeks and how best to cope with them. Four weeks later drivers were given feedback on their responses in the initial session, and asked about situations that had occurred, coping styles and strategies used, and whether the training had been useful.

50 US Flight Safety Foundation's recommendations on FRMS (USA, 2009)

Source: (Caldwell, Mallis et al. 2009)

Involved regulators / organisation(s): US Flight Safety Foundation

How fatigue is addressed: By providing guidance to organisations wishing to develop FRMS.

Evaluation outcomes: Not known

Description: Develop a fatigue risk management policy; formalise awareness/education programmes; create a crew fatigue-reporting mechanism with associated feedback, procedures, and measures for monitoring fatigue levels; develop procedures for reporting, investigating and recording fatigue incidents; implement processes and procedures for evaluating information on fatigue levels and fatigue-related incidents, implementing interventions and evaluating their effects. The Foundation recommends FRMS be used for ultra-long range operations.

51 CASA guidance on FRMS (Australia, 2009)

Source: (Caldwell, Mallis et al. 2009)

Involved regulators / organisation(s): Civil Aviation Safety Authority

How fatigue is addressed: Impact areas an FRMS must consider. Sleep opportunity provided by schedules; sleep obtained by personnel to indicate fitness for duty; hours of wakefulness; circadian factors; sleep disorders; operational demographics.

Evaluation outcomes: Not known

Description: No further details.

52 Extended stopover evaluation in long-haul air pilots (multinational, 2005)

Source: (Gundel, Åkerstedt et al. 2005)

Involved regulators / organisation(s): European Committee for Aircrew Scheduling and Safety, Singapore Airlines, Massey University, NZ

How fatigue is addressed: Three- compared to normal two-night stop-over in Los Angeles for pilots flying from (15 h flight) and back to (17 h flight) Singapore.

Evaluation outcomes: Diaries, actigraph watches, palm-top performance test probes, in-flight sleep recordings. Find pilots fragment sleep because try to sleep on both Singapore and Los Angeles time. Only 17 per cent of sleeps over 6.5 h. 3.4 versus 4.7 sleep periods on two- versus three-day layover. Pilots sleep 5.9 h more on three-day layover. But no increase in flight alertness after a third night stop-over.

Description: No further details.

53 Train-the-trainer health and wellbeing module (USA, 2005)

Source: (Krueger and Brewster 2005; Krueger, Belzer et al. 2007)

Involved regulators / organisation(s): FMCSA, ACTRI.

How fatigue is addressed: Train-the-trainer programme in which fatigue is integrated as one of several problems that can be countered by addressing the general poor health of American truck drivers.

Evaluation outcomes: Wellness training now part of new entrant training for truckers in USA. Related and motivational “road athlete” programme developed by www.occupationalathletics.com beginning to report positive results.

Description: In the late 90s the FMCSA has run a nationwide train-the-trainer programme *Mastering Alertness and Managing Driver Fatigue* in the trucking industry. In this second wave of training, the *Gettin’ in Gear* course was offered alongside the *Mastering Alertness* course from 2002-6, as several bodies grew concerned about general health and wellness of truckers. The wellness course addresses tobacco use, obesity, eating habits, exercise, stress and mental fitness; and what to do about these issues (rejuvenate, refuel, relax, relate).

Driving fatigue course materials are instructors manual, 52 powerpoint slides, 20-question ice-breaker quiz, 75-page and 20 minute video Truckers Guide to Sleep, and pamphlets on sleep disorders, strategies. 10-step programme laid out for Corporate implementation of fatigue countermeasures: 1) obtain a commitment of solid support from management, championing a corporate-wide fatigue countermeasures programme; 2) obtain a management and employee written agreement to cooperate in the tenets, principles and commitments to resources for a successful programme; 3) provide wellness and fatigue awareness training to all employees throughout the company; 4) involve employees' families in the process, and in the programme to ensure support at home; 5) make the fatigue countermeasures programme part of the health and safety culture of the company, particularly because of the medical implications involved; 6) establish non-punitive medical screening, especially for diagnosis and treatment of sleep disorders and other controllable medical problems; help drivers obtain treatment; 7) pay attention to worker rest and scheduling (circadian rhythms) and ensure dispatchers and driver managers understand the implications of working or resting at select times of the physiological day; 8) inform clients (shippers & receivers) that your company is implementing a new fatigue countermeasures programme to enhance highway safety; enlist their understanding and cooperation; 9) establish the fatigue countermeasures programme for a 2-3 year trial period before gauging its effectiveness; tweak it along the way; 10) predetermine what the measures of programme effectiveness will be; then collect them regularly to permit accurate assessment of the utility and cost-effectiveness of your programme. As part of the roll-out industry representatives were made to understand that a lifestyle focused on health and wellness is a precursor to overall driver safety consciousness ie ‘drivers and employers adopting a wellness lifestyle will be more likely to enact proper FMPs, at corporate and individual levels.

54 Energy Institute guidance for managing fatigue in transport in oil industry (UK, 2005)

Source: (Gall 2006)

Involved regulators / organisation(s): Energy Insitute

How fatigue is addressed: Education of all workers, and possibly families, on fatigue influences, and how to monitor for fatigue. Recommends sleep contracts and increasing flexibility of scheduling. The risk of fatigue in operations should be carried out.

Evaluation outcomes: Not known.

Description: Managers shoud provide appropriate education, advice and policies on fatigue that apply to all workers, not just drivers. These should account for the effects of medicines and food on alertness, and monitoring for fatigue indicators. Managers should ensure medical surveillance, fitness for duty and consider the use of sleep contracts and increasing the flexibility of scheduling. The worker's families should also be educated about fatigue. The guidance goes on to detail a risk assessment checklist: Factors to consider as a minimum in risk assessments are shift length; schedules worked; breaks during the shift; rest periods between shifts; nature and demands of job; sleeping patterns of staff; working environment; travel time before and after shift; substances used likely to affect alertness; and age.

55 Heavy vehicle driver reform (Australia, 2008)

Source: National Transport Commission, (Gander, Hartley et al. 2010)

Involved regulators / organisation(s): National Transport Commission; Australian Transport Council

How fatigue is addressed: Two types of FMP opt-out offered as alternative to hours of work legislation; FMP type contingent on how developed the company's fatigue management is, and size and culture of company. In either FMP, knowledge and awareness, competencies for fatigue risk management (tackling and preventing fatigue by driver, roster design by scheduler) are outlined and assessed.

Evaluation outcomes: None yet.

Description: Standards outlined for basic or advanced fatigue management. Transport and Distribution Training Package reviewed every 3 y. Can be used to give desired compentencies to anyone in transport supply chain, including safety managers who can use it to underpin design of assessment tools and further training. Advanced fatigue management offers increased flexibility to operator. **Basic Fatigue Management** opt-out covers scheduling and rostering; fitness for duty; fatigue knowledge and awareness; responsibilities; internal review; records and documentation. To be able to operate more flexibly, but still within hours of work legislation, organisations must show compliance with 6 standards corresponding to the stated influences on fatigue. **Advanced Fatigue Management** opt out covers Training in knowledge and skills to manage fatigue. Documentation of limits and controls. A customised and auditable SMS, with controls specific to the fatigue risks of the company's operations. The system must address minimum break in 24 h; minimum continuous 24 h free of work; minimum sleep opportunity; maximum h work in 24 h; max work in 14 and 28 d. Specify normal limits based on these parameters, how often they will be surpassed, and control measures used to manage the elevated risk when this happens. Outer limits are defined by expert and research opinion and must not be exceeded.

56 FMP intervention in fresh produce transporter (Australia, 1995-2005)

Source: (Nolan 2005)

Involved regulators / organisation(s): Nolan Interstate Transport

How fatigue is addressed: Research-based driver training about fatigue.

Evaluation outcomes: Accidents per truck per year. Trend showing Nolan accident rate per truck continually decreasing from 1998 to 2004, and still lower than national average.

Description: Key market destination up to 2000 km away by road. Company provides 25 h driver development training every year. Participator in Queensland Transport FMP pilot. 1995 needs analysis through meetings, surveys with drivers and operations staff identified what scheduling needed to address. Over next 5 to 6 months 20 meetings held with drivers. First step agreed was to analyse fatigue risk before going further. Schedules then evolved through consultation. The process identified normal and outer operational limits, the latter to be used only exceptionally. Similar process for rostering; readiness for duty; time not at work. Nolan also embarked on Trucksafe programme concerning awareness around health and related fatigue issues. Also medical screening; drug information campaigns and monthly newsletter. Management practices reviewed, including selection processes; workplace conditions. Finally, management of compliance and coercive action reviewed and incorporated into FMP.

57 NHTSA education programme (USA, 2002)

Source: (NHTSA 2002)

Involved regulators / organisation(s): National Highway Traffic Safety Administration in collaboration with National Center on Sleep Disorders Research and National Institutes for Health.

How fatigue is addressed: Education programme for US shiftworkers to give knowledge and awareness of causes of fatigue and countermeasures. Guide on how to implement programme in workplace given, in which changes to the work environment and a training evaluation are also encouraged.

Evaluation outcomes: Pre- and post- evaluation of knowledge recommended but no evaluations given!

Description: Education programme for US shiftworkers "The Road to Preventing Drowsy Driving Among Shiftworkers". Developed on consultation with shiftworkers. 6 x 15 min group education sessions, video, brochures, poster and reminder card provided. Gives knowledge and awareness of fatigue causes, how to identify fatigue, and coping strategies. Describes how to deal with sleep disorders, pressure from family and friends. Work environment changes encouraged (lighting, food, incentives). Step-by-step implementation guide for workplace education programme. 1. Implementation plan and budget. 2. Pre-programme benchmarking with questionnaire. 3. Determine and implement worksite environment-based changes. 4. Schedule communication and education. 5. Programme kick-off. 6. Display programme materials. 7. Evaluation with post-intervention questionnaires. 8. Final report to management.

58 Queensland guidelines on FRMS (Australia, 2010)

Source: (Queensland:Government 2010)

Involved regulators / organisation(s): Queensland Transport

How fatigue is addressed: Guidelines for implementing FRMS based on latest knowledge.

Evaluation outcomes: Not known

Description: Current recommendations on implementing FMP in Queensland, Australia as part of obligations in meeting the Occupational Health and Safety guidelines. Fatigue managed as a risk in same way as chemicals i.e. what is the level of risk and what are the corresponding control steps that should be taken? This is done at each of the five levels of ‘defences in depth’. Knowledge and awareness conveyed in 3-module training package. Details how to custom-design, develop and implement an FRMS, using largely defences in depth philosophy (Dawson and McCulloch 2005). Steps are 1. Define governance structure; 2. Conduct a fatigue risk assessment; 3. Design and document Defences in Depth strategies; Design a training process; Complete FRMS document and implement it. Also emphasises importance of underlying culture and senior management commitment, local champions, identifying roles and responsibilities and other principles of effective change management.

59 Flight Safety Foundation FRMS model (Multinational, 2010)

Source: (Gander, Hartley et al. 2010)

Involved regulators / organisation(s): Flight Safety Foundation

How fatigue is addressed: Fatigue risk management policy; Education and awareness; Crew fatigue reporting mechanism; Procedures for monitoring fatigue; Procedures for reporting, investigating and recording fatigue incidents;

Processes for evaluating info on fatigue levels and incidents, intervening and evaluating the interventions.

Evaluation outcomes: Not known

Description: No further details.

60 Burlington Northern SantaFe fatigue management (USA, 2010)

Source: (BNSF 2010)

Involved regulators / organisation(s): Burlington Northern Santa Fe Railway

How fatigue is addressed: Following FMP components embedded within an SMS framework: predictable work cycle times; 14 h rest guaranteed; napping policy; resting facility survey; education and discussion at safety summit.

Evaluation outcomes: No evaluation for whole programme.

Description: FM within SMS framework: Risk identification processes. Job safety analyses. Knowledge of safety and operating rules by employees. Employee empowerment as part of Safety Vision and Closed Loop Safety Process, where employees can stop work they think is too risky. Employee involvement eg safety summits. Safety communications, campaigns. Safety training. Safety concerns fed back. Each operating division and shop has a Safety Action Plan, which provides a complete safety programme, with risk identification procedures, employee participation and committees, safety communication, safety incident reporting procedures, emergency response plan and other safety inititives. Effectiveness of Safety Action Plan is reviewed. There are daily job safety briefings for all work teams. Each BNSF field supervisor conducts 1000 operational observations annually, and there are over 775,000 operational tests across the network. Top three in US for safety record. Invests extensively in developing and managing safety programmes. Large organisation, 35 full-time safety managers.

61 ALPA policy on FRMS and SMS (USA, 2008)

Source: (ALPA 2008)

Involved regulators / organisation(s): American Airlines Pilot Association

How fatigue is addressed: FRMS elements:FRM policy; education and awareness programmes, including understanding of FRM concept; processes for identifying, reporting, investigating fatigue risk based on objective and operational data; processes for monitoring self-generated reports from crew; incident reporting, investigating.

Evaluation outcomes: Not known.

Description: FRMS can operate within SMS but not necessary. SMS programme should include; commitment to SMS from CEO; documented lines of responsibility; active involvement of affected employees to an open reporting system (just safety culture); documented and robust safety risk management programme; documented process for collecting and analysing safety data and implementing corrective action plans; continous improvement process. FRMS can well be integrated into an SMS or implemented using SMS principles. Additionally, FRMS recognises the need to manage flightcrew workload and schedules with the aim of preventing both types of fatigue; manage duty period immediately before a flight; limit total duty times to prevent cumulative fatigue; Provide adequate sleep opportunity. An FRMS is a data-driven ongoing adaptive process that can detect fatigue risks and develop and evaluate control measures.

Appendix B – Summary of the inventory

Table 1. Summary of FMP inventory. The table summarises each FMP in the inventory, where Inventory No. is that number corresponding to each of the numbered entries in Appendix A. Each entry is described according to the country and sector in which it was carried out, and whether can be best described as (i) a pilot/demonstration FMP project; (ii) standards or guidelines issued to organisations; or (iii) an FMP carried out by an organisation. The number of organisations involved in the FMP are given. Elements of each entry are summarized according to whether they involve scheduling management; a programme of elements; risk management approaches or training elements. Where there is training, the target of the training is indicated (D = driver; M = manager). We also indicate where there were attempts to (a) give feedback to drivers about their fatigue or attempts to manage their fatigue; (b) improve the work environment; (c) screen and manage sleep disorders or (d) improve general health. In describing the implementation process, we indicate whether a driver consultation was part of the FMP; whether the FMP was informed by baseline measures specific to the organisation; or whether the organisation could opt out of legislation in return for implementing an FMP. In describing the evaluation we indicate the evaluation design (where an evaluation was carried out), and whether the evaluation, programme description or the recommendations made about evaluation involve independent evaluation; cost measures; accident or injury measures; performance measures; operational measures; or self-reported fatigue or knowledge. (Y = Yes and N = No).

	Description						Steps taken									Implementation			Evaluation						
Inventory No.?	Country?	Sector?	Pilot / demo?	Stds / guide?	By O?	No. O ?	Scheduling ?	Program?	risk mgmt?	Training?*	Who is trained?**	Feedback?	Work environ?	Slp disorder?	Gnl health?	Consultation?	Baseline?	Opt out?	Design?	Independent?	Costs?	Accs, injuries?	Performance?.	Operational ?	Self-report?
1	NZ	road	Y	N	N	.	Y	Y	.	.	.	N	.	.	.	.	.	Y	O FMP O	N	Y	.	.	.	.
2	USA	road	Y	N	N	50	Y	N	.	ttt	D+M	.	N	Y	N	.	.	N	FMP O	.	.	.	.	.	Y
3	USA	road	N	Y	N	.	Y	Y	.	direct	D+M	.	Y	Y	Y	Y	.	N	.	.	.	.	.	.	Y
4	UK	all	N	Y	N	.	.	Y	Y	.	.	.	Y	.	.	.	.	N	.	.	.	.	.	.	.
5	Sweden	road	N	N	Y	.	.	.	.	direct	D	Y	N	N	N	N	.	N	FMP O	.	N	Y	N	.	.
6	several	road	N	N	Y	1	.	Y	Y	N	N	N	Y	N	N	N	.	N	.	.	.	.	.	.	.
7	USA	road	Y	N	Y	1	.	Y	N	N	N	Y	N	N	N	.	.	N	.	.	.	.	.	.	.
8	Canada	air	Y	N	N	.	.	Y	N	direct	.	N	N	N	N	Y	Y	N	.	.	.	.	Y	.	.
9	NZ	road	N	N	Y	6	Y	Y	N	ttt	D+M	N	Y	Y	Y	Y	Y	N	O FMP O	Y	N	N	N	N	Y
10	Australia	road	Y	Y	N	.	Y	Y	N	.	D+M	N	Y	Y	Y	Y	Y	Y	FMP O	Y	N	Y	Y	Y	Y
10	Australia	road	N	Y	N	6	Y	Y	N	.	D+M	N	Y	Y	Y	Y	Y	Y	O FMP O	Y	Y	N	N	N	.
11	Australia	road	Y	Y	N	1	Y	N	N	N	N	N	Y	N	N	N	Y	Y	O FMP O	Y	N	N	Y	N	.
12	Australia	road	Y	Y	N	.	Y	Y	Y	direct	D	N	Y	Y	Y	.	.	N	.	.	Y	Y	Y	Y	Y
13	several	road	Y	Y	N	.	.	.	N	ttt	D+M	N	N	N	N	Y	.	N	.	.	N	N	N	N	Y
14	USA	road	Y	N	Y	.	N	N	N	N	N	N	N	Y	N	N	N	N	O FMP O ©	N	N	N	N	N	Y
15	USA	road	Y	N	Y	1	N	N	N	direct	D	N	N	Y	Y	.	.	.	O FMP O	Y	N	N	N	Y	Y
16	Australia	road	Y	N	Y	117	N	N	N	N	N	Y	N	Y	Y	.	N	Y	O FMP O	Y	N	Y	N	N	Y
17	UK	air	.	N	Y	1	Y	Y	Y	direct	D+M	.	Y	Y	Y	Y	Y	N	O FMP O	N	.	.	Y	Y	Y
18	several	rail	Y	N	Y	.	Y	N	N	N	N	N	N	N	N	Y	Y	N	O FMP O	Y	N	N	N	N	.
19	several	road	Y	N	Y	7	N	Y	N	ttt	D+M	.	N	Y	N	Y	N	N	O FMP O	Y	Y	Y	Y	Y	Y
20	Canada	rail	Y	N	Y	.	Y	Y	N	direct	D+M	N	Y	N	N	Y	Y	N	O FMP O	Y	N	N	Y	Y	Y
21	France	air	Y	N	N	.	Y	Y	Y	direct	D+M	.	.	.	.	Y	Y	N	.	Y	.	.	.	Y	.
22	Germany	road	Y	N	Y	1	Y	Y	N	direct	D+M	Y	N	Y	Y	N	.	N	O FMP O	.	N	N	N	N	Y
23	USA	road	Y	N	Y	1	Y	N	N	.	.	N	N	N	N	N	Y	N	O FMP O	N	Y	Y	N	N	.
24	USA	road	Y	N	Y	1	Y	N	N	direct	D+M	Y	N	N	N	.	Y	N	O FMP O	N	.	Y	N	Y	.
25	Australia	rail	N	N	Y	1	Y	N	N	.	.	N	N	N	N	.	Y	Y	.	N	.	.	.	.	.
26	USA	sea	N	N	Y	1	Y	Y	Y	direct	D+M	N	Y	N	N	Y	Y	.	.	.	N	N	N	N	N
27	UK	air	N	Y	Y	1	N	N	N	direct	D+M	N	N	N	N	.	.	N	FMP O	.	N	N	N	N	Y
28	USA	rail	N	N	Y	1	Y	Y	N	direct	.	Y	Y	N	N	.	.	N	O FMP O ©	Y	N	N	Y	N	Y
29	Australia	road	N	Y	N	.	N	N	N	ttt	D+M	N	N	N	Y	N	N	N	.	.	.	.	.	.	.
30	USA	air	Y	N	Y	1	N	N	N	.	.	N	N	N	N	.	.	N	O FMP O ©	Y	N	N	Y	N	.
31	Australia	road	Y	N	Y	3	Y	Y	N	.	.	N	N	N	N	N	N	N	O FMP O ©	Y	N	N	Y	N	N
32	USA	road	Y	Y	N	.	Y	Y	N	.	D+M	N	Y	Y	Y	Y	Y	N	O FMP O	.	Y	Y	Y	Y	Y
33	USA	sea	Y	Y	N	.	Y	Y	N	direct	D+M	.	Y	.	.	Y	Y	N	.	.	.	.	.	.	.
34	USA	sea	Y	N	Y	1	Y	N	N	.	.	N	N	N	N	.	N	N	.	.	.	Y	.	.	Y
35	USA	sea	N	N	Y	1	Y	Y	N	direct	D+M	N	Y	N	Y	Y	.	N	.	.	.	.	Y	.	Y
36	USA	all	Y	Y	N	.	N	N	N	ttt	D+M	N	Y	N	N	N	N	N	.	.	.	.	.	.	Y
37	USA	air	N	N	Y	1	Y	Y	Y	direct	D+M	.	.	Y	N	.	.	N	.	N	.	Y	Y	Y	Y
38	NZ	air	N	N	Y	1	Y	Y	Y	.	.	.	.	.	.	.	Y	N	.	N	.	Y	Y	Y	Y
39	USA	air	N	N	Y	1	Y	Y	N	direct	D+M	N	N	N	N	N	N	N	.	.	.	.	.	.	.
40	USA	road	N	N	Y	1	Y	Y	N	direct	D+M	N	N	N	Y	N	N	N	.	N	.	.	.	.	Y
41	Canada	sea	Y	Y	.	.	Y	Y	N	direct	D+M	N	N	.	.	Y	Y	N	.	.	.	.	.	.	.
42	Australia	rail	N	N	Y	1	Y	Y	N	direct	D+M	N	Y	N	N	Y	.	N	.	Y	N	N	N	Y	N
43	Australia	road	N	Y	Y	1	.	Y	Y	direct	D+M	N	Y	N	N	.	Y	N	.	.	N	Y	N	N	Y
44	USA	road	Y	N	.	.	N	N	Y	direct	D+M	Y	N	Y	N	.	.	N	.	.	.	.	.	.	.
45	Canada	air	N	Y	N	.	Y	Y	Y	direct	D+M	.	Y	Y	.	Y	.	N	O FMP O	.	Y	Y	Y	Y	Y
46	USA	sea	N	N	Y	1	N	Y	.	direct	D	N	Y	N	N	Y	.	N	.	.	.	.	.	.	.
47	USA	sea	Y	Y	Y	23	Y	Y	.	direct	D+M	.	Y	N	N	Y	.	N	O FMP O	N	N	Y	N	Y	Y
48	Canada	road	N	Y	N	.	Y	Y	.	direct	D+M	.	Y	.	.	.	Y	N	.	.	.	.	.	.	.
49	Australia	road	Y	N	Y	1	N	N	N	direct	D+M	Y	N	N	Y	Y	N	N	FMP O	Y	N	N	N	N	Y
50	USA	air	N	Y	.	.	.	Y	Y	direct	D+M	.	Y	Y	Y	.	Y	N	.	.	.	.	.	.	.
51	Australia	air	N	Y	.	.	Y	Y	Y	direct	D+M	.	Y	Y	.	.	.	N	.	.	.	.	.	.	.
52	several	air	Y	N	Y	1	Y	N	N	.	.	N	N	N	N	N	N	N	O FMP O ©	Y	.	N	Y	N	.
53	USA	road	N	Y	.	.	Y	Y	N	ttt	D+M	Y	Y	Y	Y	.	.	N	.	.	.	.	.	.	.
54	UK	road	N	Y	.	.	Y	Y	Y	direct	D+M	.	Y	Y	Y	.	.	Y	.	.	N	.	.	.	.
55	Australia	road	N	Y	.	.	Y	Y	Y	direct	D+M	.	.	.	.	.	.	N	.	.	.	.	.	.	.
56	Australia	road	N	N	Y	1	Y	N	N	direct	D	.	N	.	Y	Y	Y	N	O FMP O	.	.	N	N	N	.
57	USA	road	N	Y	.	.	Y	N	N	direct	D	N	Y	N	N	N	N	Y	.	.	.	N	N	N	Y
58	Australia	road	N	Y	.	.	Y	Y	Y	direct	D+M	.	Y	.	.	Y	Y	N	.	.	.	.	.	.	.
59	several	air	N	Y	.	.	Y	Y	Y	direct	D+M	.	.	Y	Y	Y	Y	N	.	.	.	.	.	.	.
60	USA	rail	N	N	Y	1	Y	Y	Y	.	.	Y	.	.	.	Y	Y	N	.	.	.	.	.	.	.
61	USA	air	N	Y	N	.	Y	Y	Y	direct	D+M	.	.	.	.	Y	Y	N	.	.	.	.	.	.	.

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