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HUMAN FACTORS FOR ENGINEERING: A SOUTH AFRICAN STUDY

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ABSTRACT

Worldwide, fatigue has been cited as a contributory cause in heavy vehicle crashes. In South Africa very little scientific evidence is available to support or reject this notion. A study was commissioned to investigate the role fatigue plays on a specific 100 km stretch of highway in the Free State province of South Africa. The section in question is a dual carriage way, in a predominantly rural environment and access to the road is limited and controlled. This road is of strategic importance and approximately a third of all traffic is heavy vehicles transporting goods between the economic hub of Johannesburg and the busy seaport of Durban. The study comprised of a detailed road safety engineering assessment and a human factor (fatigue) study. Heavy vehicle crashes constitutes almost half of all the crashes occurring on the stretch of road. The crash analysis revealed that this section of the road has an over-representation of roll-over, rear-end and side swept crashes. Internationally these types of crashes have been associated with fatigue. The study section has been described as “boring” and “long” by the drivers participating in the fatigue survey. This paper provides a brief overview of the findings from site inspection, health assessment and crash analysis. The paper then reports on the driver fatigue study where self-reported questionnaires were administered to drivers frequenting the road. Driver responses contributed to a better understanding of where and when fatigue sets in on the N3 Route. The fatigue study provided the researchers with a better understanding of the context in which fatigue occur. The paper concludes with recommendations for engineering measures which could potentially alleviate fatigue along the N3 Route.

Keywords*:* *human factors; fatigue; engineering measures; driver monotony.*

1. INTRODUCTION

Driving a motor vehicle places high demands on an individual. A driver constantly has to maintain a high level of accuracy, attention and vigilance to stay safe on the road (McCart,Ribner,Pack,and Hammer: 1996). Safe driving would generally be achievable under ideal conditions, when drivers are well-trained, well-rested and well-behaving and when road environments are simple and undemanding. Unfortunately driving conditions are often not ideal and drivers have to negotiate tasks and roads that require additional attention that increases in mental workload, requiring intense concentration and alertness in order to drive safely. On the other hand too little mental workload on drivers, for example when traversing long and monotonous roads, could influence the level of fatigue that a driver experiences (Roberts, Rodwell, and Harris, 2011).

Reviewing the different definitions for drowsy driving or fatigue, it is concluded that driver fatigue is characterised by a declining state of awareness that influences the physical aspects (Brookhuis, De Waard, Kraaij,and Bekiaris, 2003; Nilson, Nelson, and Carlson, 1997) as well as mental aspects (Schutte and Maldondo, 2003; McCart et al., 1996) of driving performance negatively. This declining state of awareness eventually ends in sleep.

Heavy vehicle drivers have to maintain even higher levels of attention and be extra vigilant due to the size of the vehicles they drive and the cargo that they carry. Literature shows that fatigue drastically increases the risk of a crash while driving (Ackerstedt and Lindstrom, 1998; Liu and

Wu, 2009). In the United States of America fatigue is implicated in 30% - 40% of truck accidents (Gander, Marshall, Bolger, and Girling, 2005). It is considered the foremost contributory cause in 31% of fatal-to-driver truck accidents. In New Zealand (Gander et al, 2005) research shows that up to 18% of truck crashes are attributed to fatigue. In New South Wales, Williamson (2007) noted that fatigue played a role in 20% of fatal crashes. In 1998, 16.6% of fatal crashes in Australia could be contributed to fatigue (Fletcher, McCulloch, Baulk and Dawson, 2005). A crash is assessed as being fatigue related if the police described the driver as being drowsy, asleep, fatigued and/or if the vehicle path suggests loss of concentration of the driver. Brookhuis et al. (2003) indicate that in the United Kingdom, 0.8% of crashes are attributed to fatigue. Brookhuis points to the fact that fatigue related crashes are more likely to be in the region of 7% - 10%. Morrow and Crum (2004) states that fatigue is the result of a wide array of factors, some an inherent function of "driving-for-work" and others being reflective of company health and safety policies. Fatigue inducing activities include: working hours; work overload; schedule irregularities; working at a variety of times; running counter to normal circadian rhythms; disturbance in sleep patterns (resulting from not finding safe and suitable places to sleep); Not getting adequate continuous sleep while working; insufficient recovery from previous work periods as well as the loading and unloading of cargo.

A number of other factors such as general health, driving hours, road environment as well as personality factors could influence heavy vehicle drivers' susceptibility to fatigue. Health related issues include: visual acuity / impairment (Wood, Chaparro, and Hickson, 2009), overweight and diabetes (Gill and Wijk, 2004) as well as substance abuse (Nelson 1997; Fletcher et al, 2005; Horne et al, 2001) that could influence levels of fatigue experienced by heavy vehicle drivers. Prolonged driving hours (more than eight hours of continuous driving (Nilson et al., 1997) or in some instances more than five hours of continuous driving (Sagberg, Jackson, Kruger, Muzet and Williams, 2004) under monotonous conditions (Horne et al., 2001) have been positively correlated with a decline in the vigilance of drivers. Fatigue related crashes have also been positively correlated with shift work (McCart et al, 1996; Schutte et al, 2003). In Australia it was found that fatigue was the cause of crashes for between 20% -30% of commercial drivers (Howard et al, 2004).

Circadian rhythm research (Ackerstedt et al., 1998) shows that the 24 hour time-of-day effect has been linked to the physiological processes that cause fatigue when driving. Sleep-related crashes have been found to occur during the early morning between 02:00 and 06:00 as well as to a lesser degree between 14:00 - 16:00 in the afternoon.

A South African study conducted by Schutte et al. (2003) indicated that South African heavy vehicle drivers tend to face the same challenges as that of their developed world counter parts with the exception that social, road and environmental conditions such as the quality of the road rest areas are less than adequate. Schutte et al. furthermore point to the fact that work-related fatigue crashes are associated with chronic sleep deprivation, over-worked employees, poorly designed work rosters and inadequate training on managing shift work. Sleep-related incidents associated with these factors include:

- Operators falling asleep while driving and crashing the vehicle;
- Delirium and loss of situational awareness;
- Equipment damage through lapses in concentration and decreased accuracy;
- High levels of absenteeism due to extended hours, and
- Evidence of employees with sleep problems.

2. BACKGROUND TO THE STUDY

The N3 Toll Concession (Pty) Ltd (N3TC) commissioned a study to investigate the over representation of crashes (Radebe, 2010) typically associated with fatigue experienced on a specific section (100 km between Villiers and Warden). The study comprised of a site inspection, an assessment of crash and health data provided by the N3TC along with a human factor (driver fatigue) study.

2.1. Site inspection results

The road is a mostly straight and situated in a rural setting that has long flat stretches mainly along Sections N3/9 and N3/8. Section N3/8X is characterised by a steep downward incline towards the town of Warden and a steep upward incline once past the town, travelling in southerly direction. It is a four lane single carriageway with a narrow painted centre island with rumble strips. In terms of engineering standards it is considered a well-designed road, with shoulders of 2,5 m, travelling lanes of 3,7 m and a painted centre island of about 0,7 m wide. From an engineering perspective the road is considered good.

2.2. Health assessment results

Health issues highlighted in the N3 health assessment that correlated with findings from international literature included severe problems with high blood pressure, blood sugar levels/glucose levels (Gill et al, 2004), tuberculosis, HIV referrals and eyesight problems (Wood et al., 2009). The health assessment indicated that drivers might have medical conditions that could potentially influence their levels of fatigue.

2.3. Crash analysis results

During a four year period a total number of 923 crashes were reported for the 100km section of the Route N3 between the towns Warden and Villiers, South Africa. Thirty seven per cent were heavy vehicle crashes. Fifty three per cent of heavy vehicle crashes occurred in the night. Most of the heavy vehicle crashes occurred in clear weather conditions (84%). Analysis of the crash data revealed that there was an over-representation of crashes that would typically be associated with fatigue (Sagberg et al., 2004; Horne, et al., 2001) such as: run-off-the-road crashes (11.2%); rear-end crashes (40.1%) and crashes in which vehicles left the road for no apparent reason (28%). Sixty-three per cent of heavy vehicle crashes occurred in the direction North-driving towards Johannesburg.

2.4. Context of this paper: driver fatigue survey

Driver fatigue was investigated through the use of a self-reported questionnaire on a specific 100 km section of the National Route N3 in the Free State Province of South Africa. The fatigue study was conducted in an attempt to understand fatigue as experienced by drivers who frequently drive along the Route N3.

3. METHODOLOGY FOR THE DRIVER FATIGUE SURVEY

3.1. Participants

Companies were selected randomly from the N3TC alert database and contacted telephonically to solicit support for participation in the project. A follow-up e-mail was sent to the companies that agreed to participate in the study, with details regarding the project. Each participating company responded with an e-mail to indicate the number of questionnaires they would require along with the address where the questionnaires must be delivered. Of the participating companies one company indicated that most of the drivers decided not to complete the questionnaires due to labour union objections against participation in the project. The questionnaire was distributed to approximately 450 drivers at companies registered on the N3TC database. Participation in the survey was voluntary and anonymous. A total number of 79 questionnaires were received by the research team. This constitutes a response rate of approximately 17%.

3.2. Research instrument and analysis of the data

The research was conducted making use of a self-report questionnaire. The questionnaire was designed to include: demographic information; operating/driving hours (refer to the number of hours that drivers drive for work); experience of fatigue on specific sections of the road; reasons as to why the drivers felt fatigue on specific sections of the road and strategies on how to address the fatigue felt on these sections of the road.

Due to the fact that a large portion of the South African population have only a basic education, care was taken to develop the questionnaire in such a manner that the drivers would be able to understand and answer the questions. Informal, practical English was used and use was made of a pictorial scale in order to make the questionnaire more user-friendly (Figure 2). A pictorial scale (WITS sleepiness scale from Maldondo, Bentley and Mitchell, 2004) was simplified and used to establish the levels of fatigue that drivers experience when reaching certain sections of the N3 toll road.

The use of the pictorial scale serve two purposes:

- To simplify the task of associating the faces with the experience of fatigue along specific sections of the road;
- To test the methodology within the context of fatigue drivers who presumably drive the road on a daily/weekly basis.

The data from the questionnaires were captured and analysed in Microsoft Excel. Responses on each of the questions were categorised, clustered and counted. The open-ended questions and questions dealing with the pictorial scale and locations on the route were analysed using a qualitative analysis approach.

3.3. Route description and application to the research

The whole N3TC route is approximately 420km in length. Although the study was focused on the specific section the hypothesis was that fatigue sets in much earlier in the journey when drivers are required to maintain vigilance and stay alert in metropolitan and mountainous areas

respectively north and south of the study section and that fatigue sets in once the drivers are past the more demanding road environments. It was the hypothesis of the research that the drivers experience fluctuations in high and medium attention demands at the start of their journey in Durban and that by the time they reach the mountainous area of Van Reenen's Pass that the onset of fatigue starts and fatigue then manifests when they reach the flat terrain of the 100 km study section. The results reported on in this paper are for the direction south to north (Durban to Johannesburg). Similar results were obtained for the direction north to south (Johannesburg to Durban) although more drivers in the survey indicated that they feel fatigued driving from Durban to Johannesburg (South to North) than from Johannesburg to Durban (North to South).

4. RESULTS FROM THE DRIVER FATIGUE SURVEY

This section gives feedback in terms of the results obtained from the questionnaires which were completed by the drivers. The questionnaire probed a number of different issues that included working experience, driving experience and hours of driving.

4.1. Demographics

Thirty eight per cent of the participants were between the ages of 31 - 40 years, followed by 33% of the drivers falling within the 51 - 60 years age category. There is a tendency among South African companies to appoint older drivers viewed as having more experience in long haul truck industry in South Africa. This could explain the high prevalence of "older" drivers in the survey. Twenty percent (20%) of drivers were in the 41 - 50 years of age category. All of the participants were male.

4.2. Driving experience

Driving experience was considered relevant as an indication of how familiar a driver is with driving a heavy vehicle as well as the challenges associated with driving a heavy vehicle safely. Most of the drivers are experienced professional drivers with more than 5 - 10 years experience. On average drivers have been working for the same company for between 5 - 10 years. Public transport is not available at all hours of the day in South Africa and the lack thereof might influence sleeping patterns as drivers need to either stay closer to work or wake-up at irregular times in order to be at work on time. This might contribute to the experience of fatigue. Most (76%) of drivers indicated that they have their own private transport to work. Three percent (3%) of drivers have access to a company shuttle. Drivers with access to their own transport at any hour of the day could be experiencing fewer problems to reach work than drivers who are reliant on public transport to reach work.. Twenty one percent (21%) of the drivers indicated that they are reliant on public transport to get to work.

4.3. Working hours

Prolonged driving hours, shift work and driving at night (Nilson et al., 1997; Sagberg et al., 2004; Schutte et al., 2003) has been identified as possible factors that could influence the onset

or occurrence of fatigue. The drivers were therefore requested to give an indication of how many days and approximately how many hours they drive for work each week.
Thirty percent of drivers indicated that they drive five days per week for work while 36% indicated they do more than 5 trips per week. Almost half (46%) of the drivers indicated that they work for more than 52 hours per week. This information is considered important as it is an indication of the minimum, average and maximum time that drivers spend driving. In South Africa driving hours are not legislated and although there are guidelines for minimum driving hours, they are generally not followed. With regard to dangerous goods truck drivers, however, there are stringent controls in place and some of the bigger companies do have a buddy/twin driver system in place.

4.4. Experience of fatigue

In order to understand how drivers recognise the onset of fatigue a tick list of possible behaviours were provided. Drivers were requested to tick the behaviour (or otherwise specify the behaviour if it was not part of the tick list) that they mostly associate with "starting to feel tired". According to the survey results most drivers (32%) indicated that they start to yawn at the onset of fatigue. Twenty nine percent stated that they start to look for things to do when they start to feel tired and 19% indicated that they struggle to keep their eyes open. Nine percent (9%) indicated they start blinking their eyes and 2% indicated they can't remember sections of the road, or how they got there. Nine per cent did not answer the question. The evening period between 18:00 and 24:00 were perceived as the most problematic for drivers (35% of drivers indicating they feel drowsy in this period).

4.5. Associating fatigue with specific sections on the Route N3

Sections of the Route N3 (Figure 1) were delimited according to known towns and landmarks such as the tollgates.

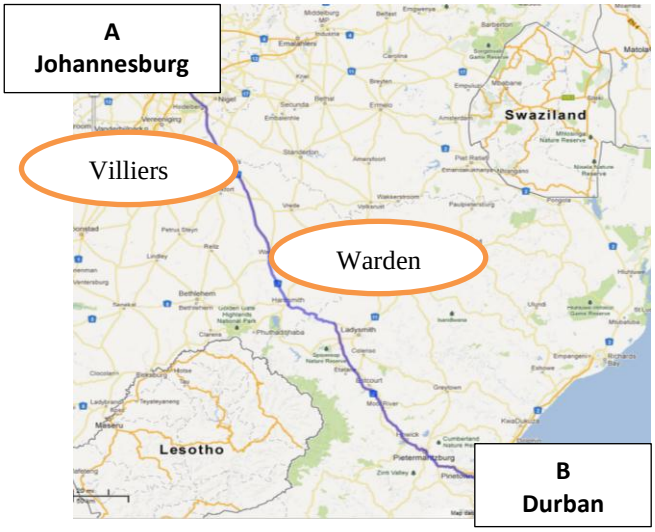

Figure 1 Route N3

The pictorial scale consists of five faces (figure 2) depicting a face as "wide awake", "awake", "starting to feel tired", "feeling sleepy" and "can't keep my eyes open".

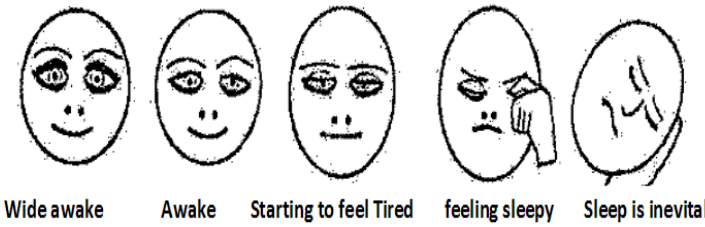

Figure 2 WITS pictorial scale (adapted from Maldondo et al., 2004)

The drivers were asked to associate a face with a particuliar stretch of road. More drivers (46%) indicated that they feel fatigued driving from Durban to Johannesburg (Figure 1: South B to North A) than from Johannesburg to Durban (32%). This finding is consistent with that of the crash analysis that indicated that more heavy vehicle crashes occurred on the northbound carriage way.

Firstly drivers were requested to indicate on which stretches of road they generally felt fatigue (figure 3 below).

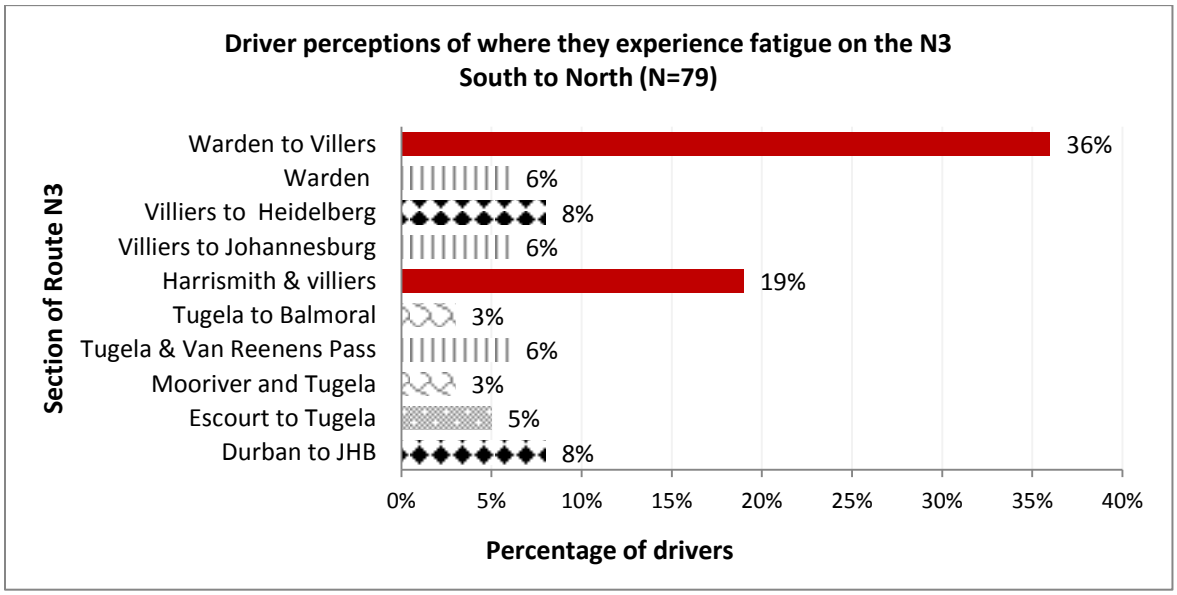

Figure 3 Experience of fatigue according to sections of the road.

Forty per cent of the drivers associated the study section between Warden and Villiers with fatigue, 20% Harrismith and 20% between Warden and Harrismith. Ten per cent of drivers did not answer this question. The section between Mooi River and Escourt were mentioned as the second stretch of road where drivers feel fatigue.

Secondly, in an attempt to verify where the onset of fatigue starts as well as the drivers' perception of where he feels "he can't keep his eyes open" the drivers were requested to associate the specific sections of the road with the face that they felt mostly described the way the felt when reaching that section (Figure 4).

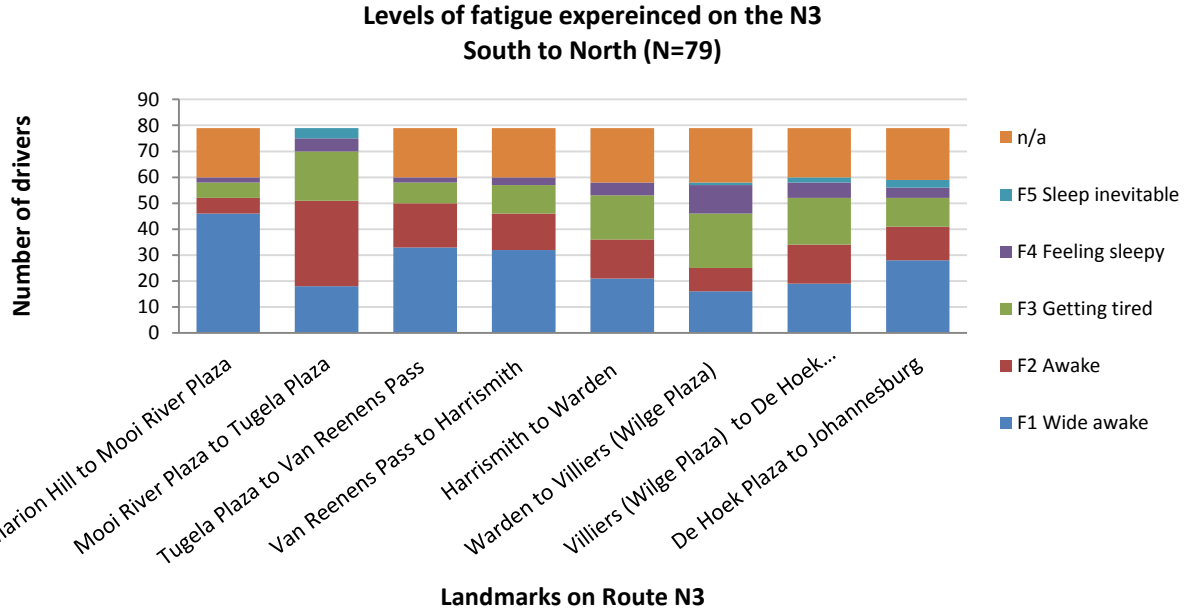

Figure 4 Onset of fatigue experienced by drivers driving from Durban to Johannesburg

Most drivers indicated that they felt wide awake for the beginning of their journey. Drivers start their journey in Durban, which is a busy congested metropolitan area. After leaving Durban, drivers have to negotiate the mountainous terrain that takes them through Town Hill and Marion Hill. For much of the journey drivers are in a state that demands heightened attention-the exception being the stretch of road after Mooi River Toll Plaza where a possible transitional period exists, leading the driver into a low attention demanding area between the Tugela Plaza- and Van Reenen's Pass. The driver again moves into a high attention demanding situation when driving through Van Reenen's pass to the other side of Harrismith after which he again enters a transitional state between Harrismith and Warden and eventually the low demanding environment between Warden and Villiers. Most of the drivers indicated that once they reach De Hoek Plaza they are more awake; knowing the end of the journey is in sight. However from Figure 3 it is clear that from the study section (Warden to Villiers) there is a small increase in the number of drivers who indicate that they feel "they are getting very sleepy" and that those who feel "sleep is inevitable". A possible explanation for this might be that the driver is in a constant state of fluctuations between these driving environments, body functions and mental states. By the time, the driver enters the low attention demanding area between Warden and Harrismith, he relaxes, which possibly accelerates the onset of fatigue and increases the risk of a crash.

4.6. Managing fatigue

Drivers were requested to provide the research team with possible solutions to alleviate fatigue along this route. Currently Route N3 has a number of lay-bys (informal stopping areas next to the road) as well as four formal truck stops with facilities such as restaurants, bathrooms and so forth.

The majority of drivers indicated that they do not stop at lay-bys next to the road, even if they are tired - rather proceed to the next truck stop or the truck stop that is a designated rest area according to their route plan. According to 67% of drivers, they prefer to make use of the dedicated truck stop facilities. Twenty nine (29%) of the drivers did not answer the question and 4% did indicate that they do make use of rest areas as well as trucks stops. Reasons as to why drivers make use of trucks stops differ although the most important factors as indicated by the drivers being: good facilities where drivers are able to shower and sleep as well as safety. The fact that a truck stop is part of the driver's company's designated stop instructions and the fact that the load is secure (crime issues) were also deemed important by the drivers. Healthy food, affordable restaurants and facilities, such as showers, personal safety and the safety of their loads on their trucks were key considerations in making use of the dedicated truck stops.

On average 24% of the drivers indicated that they stop and rest for a period between 4 - 6 hours. Almost the same percentage of drivers (23%) indicated that they only stop for less than an hour and 15% of drivers that they only stop for 1 - 2 hours to rest.

Drivers felt that more rest areas and truck stops should be available on Route N3. This was by far the biggest preference in terms of alleviating fatigue. Engineering measures that drivers thought could contribute to alleviating fatigue included ideas regarding the separation of traffic flow (heavy vehicles and light vehicles) as well as rumble strips on the edge of the road and in the middle of the road. Driver campaigns, bill boards and placement of interesting features next to the road were the next group of considerations.

5. DISCUSSION OF FATIGUE SURVEY FINDINGS

It seems that fatigue probably do play a role in crashes on this section of the Route N3. Drivers participating were mostly experienced drivers and most of the drivers seem to have been in the employ of their current employer companies for a number of years. This suggests that companies employ and mostly retain the skilled drivers in their employ. The majority of drivers were either middle age or older drivers possibly indicating the operator companies' preferences to employ drivers with more experience.

Drivers indicated that they do experience fatigue on some sections of the Route N3. Part of the reason as to why drivers feel fatigue might be the number of hours and days that drivers work per week. Driving hours in South Africa is not regulated. From this study it is clear that this is something that is in need of attention to address the fatigue issue. The driving hours and the regulation thereof will need to be considered in the light of drivers "being paid per trip".

Except for health and transport to work, lifestyle issues were not really included in the survey. Lifestyle and monetary probes were purposefully not included in this survey in order to limit the potential of drivers perceiving the answering personal questions as a threat. It is important that companies acknowledge health problems in a positive and non-threatening way by organising

company sponsored health days and information sessions in an attempt to encourage drivers to take responsibility for their health.

Drivers illustrated that they recognise the onset of fatigue. This could again have important implications for the design and implementation of fatigue education and awareness campaigns. Findings indicated that the onset of fatigue is mostly recognised when drivers start to yawn, blink their eyes or start looking for things to do. When the onset of fatigue is recognised, the ideal situation is for the driver to stop and rest. Although the majority of drivers indicated that they do stop and rest, there were clear indications that drivers are faced with numerous problems that deter them from stopping when they feel tired. The most prominent concern was the concern for personal safety. Most of the drivers indicated that they stop at designated truck stops. These truck stops are allocated on the drivers' route plans. However, this could again have implications for awareness and education of controllers and supervisors to manage fatigued drivers along the route when they report to be fatigued and when they are not close to a designated stop/rest area.

Designated truck stops are considered safe in terms of personal safety as well as the fact that the load on the truck is relatively secure at these truck stops. The most important other considerations for criteria of a "good" truck stop were good facilities and restaurants. In terms of recommendations from drivers it was put forward that additional truck stops might be needed along the road in order to alleviate fatigue.

The study section between Villiers and Warden (also Harrismith) and to a lesser degree the section between Mooi River and Tugela Plaza was mostly associated with feelings of severe fatigue. From the research findings it can be derived that drivers do experience fluctuations in levels of attention demand when travelling through different sections of the Route N3.

6. LIMITATIONS OF THE STUDY

No demographic information related to gender, age, type of driver and so forth were provided in the N3TC database. It was therefore not possible to correlate crash characteristics (specifically crashes that are thought to be associated with fatigue) with age groups, gender and so forth. Only seventy nine questionnaires were received back (17% return rate) and although a better response was expected due to the targeted nature of the survey, the survey is deemed to be representative of the companies participating in the survey. Unfortunately this low response rate makes it difficult to generalise the findings.

7. RECOMMENDATIONS

Fatigue is normally seen as a *contributory factor* in road traffic crashes. It is therefore important not to address the problem in terms of one solution but to follow a holistic approach. A holistic approach would include: engineering measures; initiatives to engage drivers in an attempt to change driver behaviour and attitudes towards driving while fatigued; strategies to engage fleet and logistics companies in an attempt to promote driver management strategies with regards to health and fatigue management as well as law enforcement approaches. However the purpose of this research was to inform the development of engineering measures which could potentially alleviate the problem of fatigue experienced on the Route N3.

Building "forgiving roads" that would not result in serious injuries or fatalities if a driver errs is not a new concept. This approach implies that roads should be designed to accommodate errant

driver behaviour as far as possible to either prevent crashes or to reduce the potential severity of injury and damage. If effective, one or a combination of treatments could be deployed in a known "fatigue hazardous location" like a long, straight, monotonous area of freeway (Jamson and Merat, 2009). Introduction of measures that "induce mild stress and perceptual novelty in order to help ward off drowsiness" could alleviate the experience of fatigue on the Route N3. But, fatigue needs to be addressed in totality otherwise it will manifest (possibly in a crash) somewhere else on the road. Drivers make decisions at three levels. These levels are strategic, tactical and operational. At a strategic level drivers generally do not have a choice in driving this route, as it is currently the only direct route between Johannesburg and Durban. The recommendation was therefore to strongly influence drivers' ability to make informed choices at a tactical and operational level. At a tactical level, drivers make decisions based on the prevailing driving conditions. This includes decisions to for example overtake other vehicles and to increase speed. Information of conditions along the route should be more prominent. Although there are variable message signs (VMS), a recommendation was to place more VMSs and to utilise these signs better, i.e. posting more and more interesting messages. At an operational level, drivers make decisions subconsciously. Perception is the basis for drivers to take a particular action. Environmental considerations are therefore important in the design of safe road. The decision to perform a particular driving task such as lowering speed or not overtaking at a particular moment largely stem from visual information that a driver receives from his environment. Based on the visual information the driver makes the decision to drive/ behave in a specific way. This decision is supported by the drivers' knowledge on how to drive in a particular situation, previous experiences in similar driving conditions and perception of own capabilities. Weller, Shlag, Van De Leuer, Jorna, and Gatti (2005) indicated that when a designing a road the designer should incorporate highly texturized road environments, allow road side objects to follow the geometry of the road and apply visual elements that can change the characteristic of the road. On the Route N3, adding additional rumble strips and road features would enhance cognitive functioning and heighten the attention levels of the drivers. Visual elements (e.g. interesting features, VMSs, etc.) can be introduced to negate the monotonous attributes of a road. Placement of stimuli (interesting features) next to the road could assist in keeping drivers attention. A further recommendation was to build a truck stop between the two towns of Warden and Villiers where drivers indicated that they experience fatigue.

8. CONCLUSION

Globally there seems to be agreement on the fact that fatigue while driving is not something that immediately starts and catches the driver off-guard. Rather it is a combination of factors that lead to a driver experiencing fatigue after driving for some time. There is evidence that suggests that many drivers are often not aware that they are driving tired until it is too late. On the other hand research suggests that drivers, although aware that they are tired, continue to drive and choose not to rest. Human factors are an important consideration in the design and maintenance of safe roads. This human factor study was part of a much larger study and final recommendations were made based on the findings from both the engineering (which has briefly been discussed in the background section) and driver fatigue study. Despite the low response rate, the study did establish a context for understanding heavy vehicle driver fatigue on the N3 Route. This could form the basis for future larger studies.

Recommendations for ameliorative engineering measures put forward based on the driver fatigue study included visual, tactical and audio stimulation.

An important finding from the literature is that monotonous road environments have proved to contribute to the occurrence of fatigue related crashes. The type of crashes most often associated with fatigue include rear-end, single-vehicle crashes, and vehicles overturning or driving into objects. Specifically visual presentation of information to drivers on the roadside had been identified as problematic. It was therefore recommended that use be made of more visual stimuli such as VMSs and audio and tactical stimuli such as different kinds of rumble strips on route between Warden and Villiers. Future research on this matter could probe measures that could "distract" the driver with visual information by finding a balance between over and under stimulation. This could include experiments that involve the placement of audio tactile devices at different sections of the road; the introduction of interesting road features next to the road or alternative uses of VMS by for example introducing trivia questions or games that are introduced at certain times of day. Further research should investigate the "limits" to which these alternative measures are introduced in order to find the balance between keeping a driver interested and stimulated to such an extent that he does not experience fatigue before reaching a designated truck stop, without introducing such a cognitive overload that drivers are distracted or more fatigued than that which they are already experiencing.

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