Final Report

Workzone Safety at the Gauteng Freeway Improvement Project

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By Arjan Apperlo

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Management Summary

The Gauteng province has the largest share of the South African population, while it covers the smallest area of land of all South African provinces. The Gauteng province, being home to Johannesburg and Pretoria, is the economic driving force of South Africa producing a third of the nation's Gross Domestic Product. Because of this economic growth people in the Gauteng area get a larger welfare and more and more of them get access to a personal vehicle. The growth is putting strain on infrastructure in the region and to make sure the population of Gauteng stays mobile the province has planned a big network improvement for the major roads in the region: The Gauteng Freeway Improvement Project.

The projects goal is to construct approximately 500 kilometres of road around the three Gauteng metros which will provide a safe and reliable strategic network and optimize the movement of traffic. The project has been split up in several contracts. During construction this project is having a big impact on traffic conditions in the area. These roadworks on roads with a lot of traffic are causing a great risk for both road users and road workers. Therefore the workzone safety is a major issue in the design project. This research focuses on workzone safety, the research goal can be described as follows:

To get knowledge of how workzone safety measures are being implemented at the Gauteng Freeway Improvement Project (GFIP), to see how this workzone safety stands according to local contract requirements and international standards and to point out where it needs improvement.

To reach this objective at first a literature study on the local contract requirements and the international standards was executed. To be able to put workzone safety at the different workzones of the GFIP to the test a checklist was put together from criteria gathered from the literature study. The checklist was used to assess the workzones.

At the start of the literature study a look has been taken at the local contract requirements. The main sources for local contract requirements are the SANRAL tender documents. These documents specify to the detail how every aspect of the GFIP should be executed. Workzone safety is an important part of these tender documents. The level of these requirements is quite high, a reference is made to the European EN1317 standard and American NCHRP Report 350 requirements. The SANRAL requirements ask for a fairly high test level of these standards.

To have a comparison for the level of the contract requirements a survey has been made of "western" standards for workzone safety. The documents used as sources for the international standards are the Dutch standards (RWS, 2005), SWOV research (SWOV , 2008) (Van Gent, 2007), European ARROWS research (ARROWS, 1999) and American NCHRP research (NCHRP, 2005).

An interesting conclusion can be made from the comparison between the local contract requirements and these international standards for workzone safety; there is not much difference in what is required for a safe workzone. Both require high performance safety measures at workzones to make them safe.

So how do the GFIP workzones stand compared to the safety standard? This will be explained by the four categories the different safety aspects have been divided in for the literature study. Site inspections were only conducted in reasonable conditions, if inspections would have been done at night or in bad weather this would have given a better view on workzone safety in the different categories.

The first safety aspect is the adjustment of road layout. This aspect focuses at traffic accommodation. At the different workzones of the GFIP this safety aspect was reasonably well looked after. The dimensions of the safety areas were according to standards, speed limits were introduced properly and also according to standards and at most sites the entrances and exits to and from the workzone were not causing dangerous situations. Still in this aspect speed is the biggest problem because although the speed limits are according to the standards the road users do not comply tot the speed limits causing dangerous situations throughout the workzones. No speed limits or law enforcements were found at site so there was no real force to keep road users from speeding.

Secondly the traffic information devices were assessed. This includes signs, warning devices, markings and flagmen. In this category a lot of standards and requirements couldn't be met. Signing was according to the standards at most of the sites but a reasonable amount of sites could not meet the standards for warning devices. A lot of the sites had badly visible markings and badly removed old markings. At one site no temporary marking had been applied. Flagmen were also a problem because although at most sites the flagmen were present they did not improve the awareness because they were often not as visible as they should have been and they were also not flagging a lot of the times or flagging in the wrong techniques.

The third category in safety aspects are vehicle guidance and restraint systems. This category is more black and white than the others because compliance of these systems can be measured and therefore there is no grey area. This category contains delineation devices, barriers and crash absorbers. Delineation is a major issue at the GFIP. The setup of delineation happens only partially according to standards; spacing and alignment is not always as it should be. But the biggest problems are broken and damaged delineation devices. Trucks seem to make a game out of running them over therefore a contractor has to replace a lot of delineators. Also the stabilisation of the delineators isn't as it should be so a lot of delineators are blown over by the wind.

Barriers are the second major part of this category. A vehicle restraint system or barrier has, according to the contract requirements, to comply with NCHRP Report 350 TL4 or the EN1317 H1 test level. To know if a system is compliant it has to be tested at a special facility. South Africa does not have such a test facility so used barrier systems either have to come from other countries or have to be tested there. Of the 3 types of used temporary concrete barrier systems at the GFIP two have been tested. The DeltaBloc barrier systems have been designed and tested to the EN1317 and comply with Test level H1. The SANRAL designed F-shape barrier is designed after the example of three American barrier types that comply with NCHRP 350 TL3. The SANRAL designed single side barrier is actually designed to be casted in for permanent use. Of these three types of barrier systems only the DeltaBloc complies with the SANRAL contract requirement. This is contradicting because SANRAL designs and issues barriers that do not comply with their own standards.

An even bigger problem than the compliance of these barrier systems is the installation. These systems are only effective as they are installed properly because the different barriers work together to absorb kinetic energy at an impact. If barriers for example are not joined properly the effect of the system is gone and the results at impact will not be safe. At a lot of the sites the installation of the different systems was not according to manufacturers standards. This caused a major safety problem. There were installation had been executed accordingly the positive effects could be seen. A lot of impacted locations have been spotted during site inspections and where the installation was good penetration of the workzone hardly occurred, even with non complying barrier systems.

The last component of this category is the crash absorbers. A lot of non complying systems like, water filled plastic barriers, filled plastic water tanks and heaps of sandbags were used. These do not comply with international standards for crash absorbers. One complying crash absorbing system was found at site but this system was not installed properly and therefore not safe.

The last category in the workzone safety assessment is miscellaneous; things like risk assessment, traffic safety officers, safety vehicles, personnel and non-personnel are important to guarantee a safe workzone. At the two site offices that were visited risk assessments and site specific sets OH&S rules were found. Safety officers and required vehicles were also found at site. At one site a safety vehicle was used for transport purposes, and this contradicts directly with the SANRAL requirements. Not much can be said about how non-personnel at site is treated and made aware of the safety issues. All personnel at all sites was wearing reflective clothing according to standards but these clothes were often dirty from the work en this made the reflectivity a lot less. But besides these small points aspects in this category were executed pretty reasonably.

All together the workzone safety at the GFIP could be improved a lot, the main line is set out but the strictness of how the line is followed should have a boost. This way a lot of unsafe situations can be avoided.

Improvement of workzone safety at the GFIP and throughout South Africa has to consist of two major things:

Firstly contractor's compliance with the safety standards has to improve drastically. Only if the used warning and safety systems are used a safe workzone can be created. Because workzones are very variable because the work is always on the move this compliance includes repeatedly checking the workzones. Making sure the workzone setup is according to standards, lane closures have been executed properly, delineation is according to standards and the workzone is closed of properly with complying barrier systems that are installed according to manufacturer's specifications. Experience in Europe shows that this result can only be accomplished if the situation is checked over and over again and if non-complying contractors are faced with the consequences.

Secondly the road user should stop treating the workzone as a normal section of highway. Speed limits need to be followed. There are two ways of reaching this goal; the first is to install speed reducing measures like speedbumps and rumblestrips. Traffic will be forced to slow down. The second way of achieving coherence with the rules is enforcing the rules. In Europe the consequences for violating of for example the speed limit at a workzone are much heavier than at a normal section of freeway. This way the road user will hopefully learn to keep the rules and help creating a safer workzone.

Preface

This report is the final report on my Bachelor Theses for my Civil Engineering course at Twente University in Enschede, The Netherlands. The research has been carried out under the supervision of the Road Safety Committee of the South African Roads Federation. The main objective was to assess the workzone safety at one of South Africa's biggest civil engineering projects at the moment; the Gauteng Freeway Improvement Project. This project is divided into work packages which are tendered to different contractor companies or joined ventures.

To be able to judge the sites on workzone safety I had to setup a standard for comparison. I used two major guidelines for these standards; the local contract requirements and international standards for workzone safety at roadworks. In a literature study I gathered the most important points of interest to put together a checklist on which the worksites could be evaluated. Next I've visited the different worksites and evaluated them with the checklist.

The differences between the local contract requirements and international standards came out to be very little but the difference between the standard and the real situation at the workzones turned out to be a lot less positive. Although workzone layout and signing was mostly according to standards a lot of things according vehicle guidance and restraint were not. A lot of non complying systems have been used and installation of systems was not according to standards. In other words the standard and requirement are not fully being followed. Therefore a lot of improvement should be made in following the standard. The most logical way of "forcing" a contractor to comply is to check on him on a regular base and ensure serious consequences when a contractor breaks the rules or doesn't follow regulations. Efforts should also be made to ensure the road users keep to the rules so workzones do not turn in to racetracks anymore.

The outcome of this research is therefore very interesting and I think it is very useful to SARF to take action and eventually follow it up with more research and tests. I've really enjoyed doing the research although it was hard work. Also a lot of problems had to be overcome to make this research a success. I couldn't have done this all by myself, so first I'd like to thank Roy Spenkelink and Harold Topper for setting me up with the people in South Africa so I got this great opportunity. For the support from Twente University I'd like to thank Ynso Suurenbroek, for looking critically at my research setup and the different products I produced, Ellen van Oosterzee-Nootenboom for helping me set up this internship and for helping me handling the cancellation of my original research project and Annet de Kiewit for stepping in when Ellen was on holiday.

For all the help with everything I'd like to thank Craig Strong; for getting me started, helping me find a new research project and taking me in to his house. Secondly I want to thank Garth Strong for the contacts in the South African infrastructural and highway construction world and the access to all the literature that was vital for the research. I'd like to thank Patrick Mullen for getting me to the construction sites and the other places to put the real situation to the test. I must also thank Michael Laubscher for giving me the opportunity to come to South Africa and allowing me to do the internship under his supervision. I'd also like to thank Craig and Mike for pushing me to see as much as the country as possible and allowing me time to do so. And last but not least my parents for the support they gave me and the bucketload of drop they took to South Africa to keep "the boss" happy.

I've had a wonderful time in South Africa; I saw a lot of the country and got to learn a lot of valuable things doing this internship and this research project. All the help I got making this possible is dearly appreciated.

Midrand (South Africa), 29 October 2009
Arjan Apperlo

Terminology and abbreviations

ARROWS – Advanced Research on Road Workzone Safety Standards in Europe

ASI – Acceleration Severity Index

DRIP – Digital Route Information Panel

EN1317 – European Standard for road restraint systems

FHWA – (American) Federal Highway Association

GDP – Gross Domestic Product

GFIP – Gauteng Freeway Improvement Project

HGV- Heavy Goods Vehicle

LDV – Light Delivery Vehicle

LON – Length Of Need

NCHRP – (American) National Cooperative Highway Research Project

NCHRP Report 350 – American standard for road restraint systems

OH&S – Occupational Health and Safety

PHD – Post impact Head Deceleration

SABS – South African Bureau of Standards

SANRAL – South African National Road Agency Limited

SARF – South African Roads Federation

SARTSM – South African Road Traffic Signs Manual

TD – Tender Document

THIV – Theoretical Head Impact Velocity

TMA – Truck Mounted Attenuator

VMS – Variable Message Sign

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1. Introduction

This chapter will give a short introduction to the research project. The first section will clarify the context of the problem that is being addressed in this thesis. Section two will explain the project which the research focuses on, section three will shortly explain the work packages the project consists of. The forth section will explain the problem that is being researched. In section five the goal of the research will be stated and section six will describe the method that will be used to reach that goal. Finally the seventh section sets out the structure of the report.

1.1 Context

The Gauteng province has the largest share of the South African population; approximately 10.53 million people (21.4%) live in this province (Statistics SA, 2009). Because Gauteng only covers 1.4 % of the land area of South Africa its population density is little over than 636 people per square kilometre (SA Info, 2007). Gauteng is the economic driving force of South Africa contributing 33.3% to the national gross domestic product and a phenomenal 10% to the GDP of Africa as a whole (SA Info, 2007).

People who live in the Gauteng area are aware that the growth in the economy, subsequent improvement in living conditions and access to private vehicles, has caused a situation where the road system in the area around Johannesburg, Pretoria and Ekurhuleni is taking strain, particularly around peak hours.

The traffic and congestion caused by the increase in vehicles in this particular region leads to a decline in the quality of life and wastage of valuable resources. The N1 between Pretoria and Johannesburg carries more than 180,000 vehicles daily. The congestion on the main routes has substantial adverse effects on the amount of time that people can spend with their families, their productivity in the workplace, levels of frustration and unhappiness of drivers, and also has an effect on the environment through excessive emissions (SANRAL, 2009).

To make sure the population of Gauteng stays mobile the province has planned a big network improvement for the major roads in the region: The Gauteng Freeway Improvement Project.

1.2 The Gauteng Freeway Improvement Project

The South African National Roads Agency Limited (SANRAL) is responsible for the development, maintenance and operation of 16 150 kilometres of roads which are considered to be of national importance, of which 2400 kilometres are tolled (SANRAL, 2009).

SANRAL has together with its partners, the metro authorities in Tshwane, Johannesburg, Ekurhuleni and the Province of Gauteng, developed the Gauteng Freeway Improvement Project (GFIP), to upgrade and/or construct approximately 500 kilometres of road around the three metros which will provide a safe and reliable strategic network and optimize the movement of freight and road based public transport. This will be done through the creation of an interconnected network of inner and outer ring-roads, and will also provide a direct link to the historically neglected areas of the South Western townships of Johannesburg (SANRAL, 2009).

The project is planned to be implemented in phases, starting with the environmental impact assessment, expanding the carrying capacity of the roads, and other improvements. The environmental impact assessment, which includes a public participation process, has begun on various sections of the road network including sections of the N14 and R21. The social and economic impact assessments are also under way. A map, Figure 1, is attached which gives details of the various aspects of the GFIP – in respect to improvements and upgrades, as well as new expansion (SANRAL, 2009).

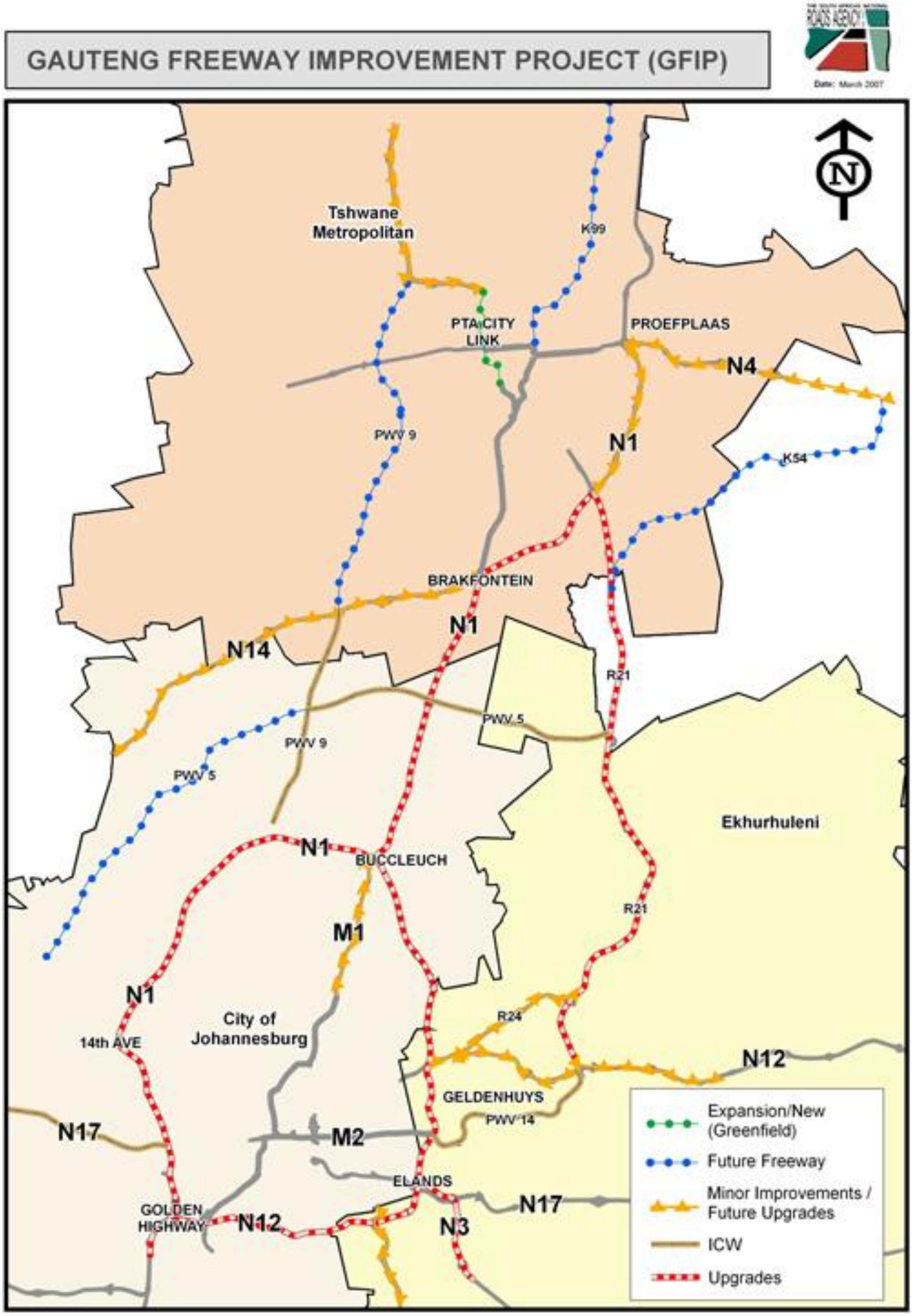

Figure 1: GFIP – scheduled improvements, upgrades and expansions (SANRAL, 2009)

1.3 Work Packages

The work on the GFIP is split up in several different workpackages, the following packages are the ones that have been visited for inspection (SANRAL, 2009):

Work Package A1 (17km):
N1 section 20 between Golden Highway and 14th Avenue – 17 km;

Work Package A2 (1km):
N12 section 18 between the Elands Interchange and the M1 Interchange – 1km

Work Package B (21km):
N1 Section 20 between 14th Avenue and Buccleuch Interchanges

Work Package C (23km):
N1 Section 20 & 21 between Buccleuch and Brakfontein Interchanges;

Work Package D1 (10km):
N1 Section 21 between Brakfontein and the R21 Interchanges – 10 km;

Work Package D2 (5km):
N1 Section 21 between the Atterbury and Proefplaas (N4) interchanges – 5 km

Work Package E1 (12km)
N3 Section 12 between Old Barn (Heidelburg rd) and Geldenhuys (M2) Interchanges – 12 km

Work Package E2 (4km)
N12 Section 18 between Reading (R59) and Elands (N3) interchanges – 4 km

Work Package F (17,6 km)
N3 Section 12 between Geldenhuys (M2) and Buccleuch Interchanges

Work Package G (18 km):
R21: Olifantsfontein to N1

Work Package H (10 km):
R21: N12 to Olifantsfontein

Work Package I (10,6 km):
N12: Gillooly's to R21

Work Package J (8 km):
R21: N12 to Pomona

1.4 Problem Description

Because of all these improvements the traffic on the different roads will be exposed to the roadworks. The other way around, workers are being exposed to trespassing traffic. It is important that safety for both traffic and workers is an important issue at the GFIP. A lot of the roadworks have already started and it looks like if workzone safety is not as important to some of the contractors as it should be. To find the cause of these unsafe situations we will first have to take a look at the local contract requirements. These requirements prescribe the different contractors what measures they have to take to accomplish a safe workzone. To see how these South African standards compare to the international standards it is important to make a comparison. After that it is important to see if South African contractors at the GFIP do their work complying with the South African contract requirements and, to get a better reading on the global view of workzone safety, if the work complies with international standards.

1.5 Research Objective

It is important that workzone safety at big roadwork projects like the GFIP is being maintained, not only for the workers at site, but also for trespassing traffic. In the Gauteng area the contractors at different sites use all kinds of safety products. The objective of this study is to show the differences in workzone safety between several roadwork construction sites and to point out where improvement in workzone safety is needed. The goal of this research study can be quoted as follows:

To get knowledge of how workzone safety measures are being implemented at the Gauteng Freeway Improvement Project (GFIP), to see how this workzone safety stands according to local contract requirements and international standards and to point out where it needs improvement.

To reach this goal the following research questions will be answered:

- What are the local contract requirements for the different work packages at the GFIP?
- What are the international standards on workzone safety at major roadworks projects?
- Does workzone safety at the construction sites meet safety requirements?
- Have the products that are used to provide workzone safety been tested and are they reliable?
- And
- What improvements in workzone safety are required at the GFIP?

1.6 Method

To make sure the research goes as planned a research model was created. This model shows how the researcher will proceed during research. By following this model all research questions will be answered.

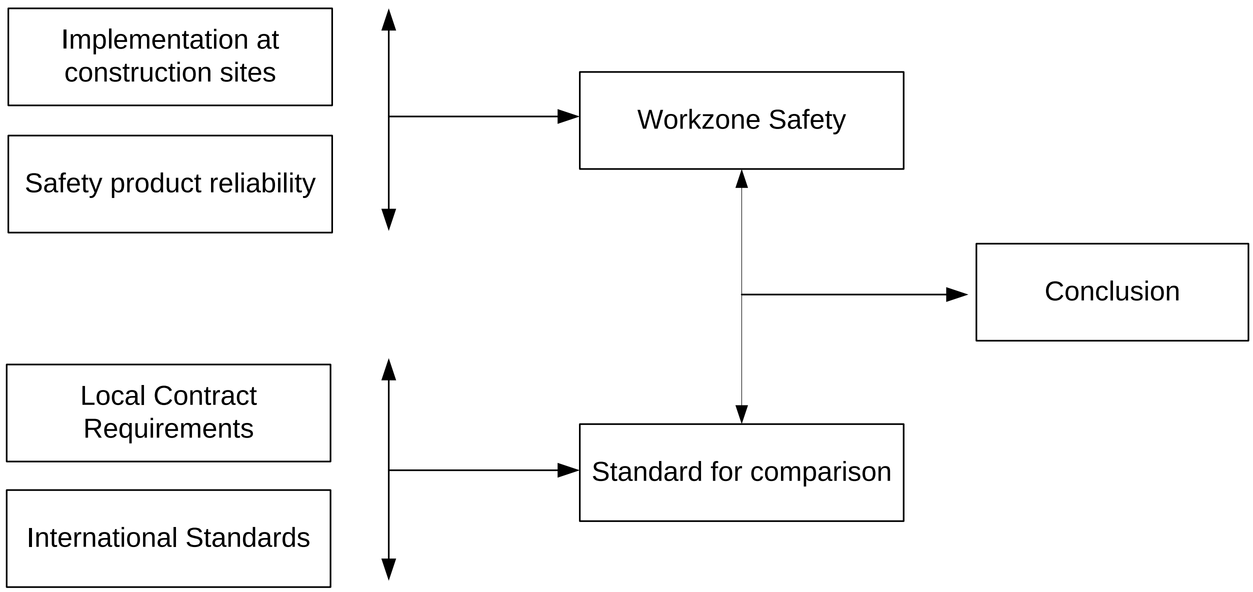

Figure 2: Research model

The research model obviously divides the research into two different parts. The top part of the research focuses on the practical side of things and the bottom part on the theoretical part. A literature study will be done on the local contracts and on international standards of workzone safety.

In the top part off the research model the first two questions of the research objective will be answered. The bottom part contains the information gathered in the literature study. A comparison between both parts covers the third question the fourth question will be answered when the used safety products are known to the researcher and the final question will be answered in the conclusion after looking at the results off the comparison.

Now an explanation will be given on each research question will be answered.

Q1: What are the local contract requirements for the different work packages at the GFIP?

To get the local contract requirements for the work packages the researcher will look in to the tender documents for the GFIP. Information on what workzone safety measures have to be taken by the contractor can be found there.

Q2: What are the international standards on workzone safety at major roadworks projects?

For the international standards the researcher will look at the two major western continents: North America and Europe. In both America and Europe there have been research projects on how workzone safety at highway projects can be standardized. In America there is the National Highway Cooperative Research Program (NHCRP) and in Europe in there was a big research project called ARROWS. Also the Dutch SWOV research and RWS requirements will be taken into account. Finally the international standards that apply for vehicle guidance and restraint systems will be researched. In America the *NHCRP Report 350* is being used and in Europe the *EN1317*.

Q3: Does workzone safety at the construction sites meet safety requirements?

To answer this question the researcher will visit and investigate the various roadworks construction sites, he will observe, ask questions and take pictures off different ways of implementing workzone safety. Data about workzone safety will be collected for every construction site. The researcher will have to compare the actual situation with the contract requirements and the international safety standard. Therefore he will put together a checklist out of the data gathered in the first two research questions. The workzone safety will be evaluated by working through the checklist. It is important to understand that any results of a safety inspection represent only a point sample of the project when the inspection was conducted. Therefore any conclusions on how effectively the traffic control system will function should include different conditions including reasonably expected traffic conditions but also adverse conditions, such as darkness and rain.

Q4: Have the products that are used to provide workzone safety been tested and are they reliable?

A comparison between the lists of NCHRP Report 350 and EN1317 approved product from America and Europe and the used road safety products will be made. Different contractors will use different products and different manufacturers. To make sure the products are safe test results will be collected. If there haven't been any tests on how the product functions this product doesn't comply with the standards and therefore the researcher will assume an unsafe product until proven otherwise.

Q5: What improvements in workzone safety are required at the GFIP?

When all previous questions are answered a conclusion can be drawn on workzone safety at the different construction sites. If the outcome for a construction site is that workzone safety is not at an acceptable level improvements can be suggested.

For answering questions Q3 and Q4 the researcher acts as an observer and he will get involved with the different contractors and producers. The involvement of the researcher makes direct observations possible. Direct observation increases the internal validity of the research because it reduces the gap between the research data and the reality.

The strong involvement of the researcher has two disadvantages on the internal validity. The organization can adjust their way of acting when they know that they are researched. This is called reactivity, but the effect decreases on the long term. The second disadvantage occurs in the long term and is called going native. The researcher becomes part of the community and the researcher risks starting to think in line with the local organization and loses his interests in the theory ('t Hart et al., 2006).

The relative long term and heavy solutions that provide safety make that a contractor will hardly be able to change the situation if he knows he is being researched. This has minimized the disadvantage of changing the way of acting of the organization. The second problem can be minimized by processing the information after it is gathered. This minimizes the inside focus during the writing process, but the data flow is quite small during this process of writing. Besides that the researcher will be with the different contractors for a very short amount of time, therefore it can be assumed that going native will not be a problem in this research.

1.7 Report setup

The structure of the report is based on the research model. This model consists of two different parts. The first part is the theoretical part containing the standards for comparison; the local contract requirements and the international standards. A checklist will be put together to be able to assess the different worksites. This part will be addressed in chapter 2. Chapter 3 covers the second part of the research which is the practical part; here the checklist will be put to the test. Also the reliability of the safety products that are used on the worksites will be checked. In chapter 4 the results of the assessments will be compared and a conclusion will be written. Finally in chapter 5 some additional actions and safety measures will be recommended for the GFIP.

2. Literature study

In this chapter the theoretical base for the workzone safety assessment will be prepared. First a short explanation will be given on what literature considers a workzone. Next the two different standards used; the local contract requirements and the international standards will be covered. Finally an explanation on the European and American safety standards for vehicle restraint systems will be given.

2.1 The Workzone

The travelling public has expectations of a freeway and because of the GFIP roadworks these expectations can't be met for a certain amount of time. To be able to accommodate a road user in a safe way a proper design of the alternate layout that piece of road is required. This design should be made in such a way that the risks are comparable to a normal freeway situation without roadworks. At roadworks extra safety measures are therefore required to keep the negative effects on safety to a minimum. Safety measures can have different goals: (Van Gent, 2007): Separating the workzone from the traffic, leading the traffic through the workzone, making roadworks and workers visible to travelling public and making the driving task easier.

In the literature several ways of setting up roadworks are given, more information on these particular research projects can be found in Appendix A. All these ways of setting up a roadworks site have a similar base. For example SANRAL (SANRAL, 2008) distinguishes a zone for informing the road users, *the advance warning area*, a zone for allowing road users to adjust their behaviour to the workzone they're approaching, *the transition area,* a zone for safety and buffering, *the buffer area*, the actual working area where the construction activities take place, *the workzone,* and an ending or termination zone where the normal road situation is restored, *the terminal area*. International research and regulations from The Dutch Ministry of Transport (RWS, 2005), CROW (CROW, 2005), SWOV (Van Gent, 2007) and ARROWS (ARROWS, 1999) show similar categorising for workzone setup. Research (Van Gent, 2007) shows that of these areas the workzone appears to be the most risky. Road workers experience working at night as being dangerous. Literature indeed shows that at roadworks the night hours generally have an increased crash rate. The number of roadworks crashes, however, is higher during the day: more than two thirds of the roadworks crashes happen in the daytime and the proportion of nightly roadworks crashes is barely higher than that of daytime crashes. This is probably due to the fact that roadworks are more frequently carried out during the day, rather than at night (SWOV , 2008).

Standardisation of work site areas regarding traffic guidance, alignment, and width of temporary lanes, as well as of individual signposts and guiding devices is assumed to strongly contribute to the solution of the safety problem at roadworks (ARROWS, 1999). During small-scale and short-lasting activities it is often difficult to use the same protection and structure. This may be caused by, for example, lack of space or relatively high costs (SWOV , 2008). Experience shows that inappropriately designed workzones are common (NCHRP, 2005). Therefore greater attention to the design of workzones may lead to a more efficient overall operation of the workzone, in terms of both traffic operations and safety.

Research (ARROWS, 1999) also shows there are great shortcomings in the area of checking of workzones, despite relevant requirements in the regulations. Prime causes here are bottlenecks in the personnel in the different monitoring posts. As a rule the contractor is then usually found to be responsible, although the avoidance of such situations by early and intensive checks would have been more sensible. In conclusion it can be established that, in addition to the optimizing of traffic sign, marking and safeguarding plans, increased efforts must be made to creating the fundamentals for the training of contractors.

2.2 Local Contract Requirements

In this section the part of the base for the assessment of workzone safety extracted from the local contract requirements will be established. The document used as a source for the contract requirements is the tender document (SANRAL, 2008) for one of the work packages. There are two major sections in this document that are relevant for the assessment of the workzone safety at the site: Section B1500 about the accommodation of traffic and Section E about the requirements of the occupational health and safety act and regulations. The information gathered from the SANRAL tender document (SANRAL, 2008) is split into four different sections based on the ARROWS research program (ARROWS, 1999) being; Adjustment of road layout, Traffic information devices, traffic guidance and restraint equipment and miscellaneous.

In this chapter there will be referred to *tender drawings*; a hardcopy of these *drawings* was available to the researcher at the office. Because these *drawings* are of an A2 size they can't be included as an appendix in this report. Reference will also be made to the *EN1317* standard and the *NCHRP Report 350* requirements. More information about these standards can be found in section 2.4.

Adjustment of road layout

This section will go into the changes made in the road layout and speed limit to be able to accommodate the workzone for the roadworks.

Lane layout and closures

The arrangements expected to be most commonly used in the contract are given on the *tender drawings*. At work on/outside the shoulders traffic shall be accommodated as indicated on these *drawings*. At long term works in the median the traffic shall be moved to the outside by changing of the lane markings to maintain the existing number of through lanes. At long term works in the median the fast lane can be closed temporarily. At short term diversion of a carriageway a minimum of two lanes with 3,3m lane widths must be provided in both directions. This will require that certain widening must be completed to provide a wide enough road surface. At long term shoulder closure at bridges the temporary barriers must be placed on the shoulder 1m away from the slow lane. At short term lane closure a minimum of 2 lanes with 3,3m lane widths shall be provided at all times. At works on cross roads and ramps at least half of the road or ramp shall be open to accommodate traffic. *TD Sections B1502 and B1503* (SANRAL, 2008)

Speed

At work on/outside the shoulders, long term works in the median and at long term shoulder closure at bridges the speed must be reduced to 80 km/h. At short term diversion of a carriageway the speed shall be reduced to 60 km/h in both directions. *TD Sections B1502* (SANRAL, 2008)

Entrance and exit of construction area

In all temporary closures, construction vehicle entrances / exits shall be allowed for as shown in the *drawings*. At work on/outside the shoulders the number of entrances that may be provided into the working space shall be restricted to a maximum of two. At long term works in the median only one entrance to the construction area shall be provided and at long term shoulder closure at bridges entrance to the construction area shall only be provided at the start of the closure. At work on/outside the shoulders, long term works in the median and long term shoulder closure at bridges construction vehicles will only be allowed to exit the construction area at the end of the closure in order to allow for acceleration in the fast lane. *TD Sections B1502 and B1503* (SANRAL, 2008)

Traffic information systems

This section will focus on the devices used to inform the vehicles approaching and passing the roadworks and required actions. Traffic signs, markings, traffic lights and flagmen are examples of these systems.

Traffic signs

The contractor shall provide, erect and maintain the necessary road signs as shown on the *drawings* and remove them when no longer required. All signs used to accommodate traffic should comply with the provisions of the latest edition of the South African Road Traffic Signs Manual (SARTSM). At short term diversion of a carriageway the travelling public shall be informed by the information signs. At works on cross roads and ramps all road signs used shall be high visibility rectangular signs. All temporary road signs required to remain in position for some time shall be pole mounted as shown on the *drawings*. All temporary road signs required to be moved more often shall be mounted on portable supports for the easy moving of signs to temporary positions. The only permitted method of ballasting the sign supports shall consist of durable sandbags filled with sand of adequate mass to prevent signs from being blown over by wind. The Variable Message Sign (VMS) shall be mounted on a trailer for moving on the site as well as outside the limits of the contract to inform the travelling public of traffic conditions. *TD Section B1501, B1502 and B1503* (SANRAL, 2008)

Warning devices

The contractor shall provide, erect and maintain the necessary warning devices as shown on the *drawings* and in accordance to the SARTSM and remove them when no longer required. At work on/outside the shoulders flicker lights shall be erected at the start of the closure for the entire construction period of each section during night time. At work on/outside the shoulders alternating flicker lights shall be used on the first pair of road signs at any set of traffic accommodation. If the fast lane has to be closed temporarily for works in the median, the start shall be indicated with a flashing illuminated arrow board, also during day time. The flashing illuminated arrow board shall be made up of light sources mounted on a backing board. A single shaft arrow will be required that can be used for both left and right directions. The light sources must be of LED type to improve visibility if used also during day time. Should construction in the median during night hours be required, the contractor shall make use of alternate lighting and flashing illuminated arrow boards. At short term diversion of a carriageway double flashing illuminated arrow boards shall be placed at the lane drops. At long term shoulder closure at bridges and short term lane closure a flashing illuminated arrow board must be placed at the start of the closure.

All vehicle-mounted rotating flashing lights shall have an amber lens of minimum height of 200 mm and shall be mounted in such a way as to be highly visible from all directions. Lights on plant shall operate continuously while the plant is working alongside sections of road open to public traffic and all LDV's and cars operating on site shall also be equipped with rotating amber flashing lights which shall be placed so as to be highly visible and operated continuously while the vehicles are manoeuvring in or out of traffic or are travelling or parked alongside roads open to public traffic. Two amber flashing lights shall be vertically mounted on top of the traffic signs at each end of each traffic accommodation section as shown on the *drawings*. The lights shall be operated during the hours of darkness. *TD Sections B1502 and B1503* (SANRAL, 2008)

Markings

The contractor shall provide, erect and maintain the necessary road markings as shown on the *drawings* and in accordance to the SARTSM and remove them when no longer required. Further all temporary road marking shall be reinstated after each shift before the road is opened to traffic and shall consist of pre-marking, and/or retro-reflective road marking paint, and or temporary road studs. *TD Sections B1503* (SANRAL, 2008)

Flagmen
Flagmen shall be provided where shown on the *drawings* or required by the specification. During the daytime, at least two flagmen shall be provided at each traffic control point in addition to the STOP/GO sign operator, one at the 80 km/h sign and a second roving to indicate to the traffic at the end of the queue to stop. At night time only one roving equipped with a Stromberg Lightman xenon strobe, or similar approved, and a torch is required at each traffic control point as well as the traffic light operator. Where sections alongside the road on the slow shoulder or median are closed to traffic, a shall be provided at the leading end of the closure during daytime. If work is carried out at night time a equipped with a Stormberg Lightman xenon strobe or similar approved, and a torch is required at the indicated positions. This shall be provided at the 80 km/h sign to warn the traffic about the closure. No shall be on duty for a period of more than 10 hours per day. Also all flagmen shall be adequately trained in the standard flagging techniques as described in the SARTSM and be provided with conspicuous clothing such as safety jackets utilizing retro-reflective and/or fluorescent panels in red, yellow and/or white. *TD Section B1503* (SANRAL, 2008)

Traffic guidance and restraint equipment
This section will give the contract information on guidance and restraint systems like delineators and barriers.

Channelization devices
The contractor shall provide, erect and maintain the necessary channelization devices in accordance with the *drawings* and remove them when no longer required. The use of drums as channelization devices shall not be permitted. Delineators shall comply with the manufacturing and reflective requirements of the SARTSM and the blades shall be reversible with dimensions as indicated on the *drawings*. All delineators shall have smooth and round edges and be mounted on a post and base. All components shall be of durable plastic material. Further all delineators shall have the lower edge of the reflective part of the delineator mounted not lower than 250mm above the road surface, they shall be capable of withstanding the movement of passing vehicles and gusting winds up to 60 km/h in typical working conditions without falling over. To achieve this, the base shall be at least 0.18 m_2 and ballasted by sandbags with sand. Finally delineators shall together with its mounting be designed such that it will collapse in a safe manner under traffic impact. *TD Section B1503* (SANRAL, 2008)

Barriers
The contractor shall provide, erect and maintain the necessary barriers in accordance with the *drawings* and remove them when no longer required. Barriers for preventing vehicles from leaving the permitted lanes shall be movable barriers with an approved safety shape design. Temporary movable barriers are to be obtained from suppliers and to be placed between the existing road and the new construction areas. Barriers shall comply with the requirements of either the European specification *EN1317* with containment level H1, or the American Federal Highways Administration Specification *NCHRP Report 350* with containment level TL4. The minimum Impact Severity Level of a barrier shall be B. The displacement width of the barrier shall not exceed the available safe width to the nearest edge of the construction.

At work on/outside the shoulders temporary barriers are to be used on the widening of the national road between the existing road and new construction. At long term works in the median a temporary barrier shall be placed between the construction area and traffic, inside the fast lane and next to the middle lane. At short term diversion of a carriageway temporary barriers shall be used to separate the traffic. At long term shoulder closure at bridges temporary barriers must be placed on the shoulder. At short term lane closure delineators shall be used to demarcate the construction area instead of barriers. At works on cross roads and ramps excavations shall be demarcated with temporary steel and/or concrete barriers at areas causing a safety hazard, else delineators can be used.

All moveable barriers shall be installed in accordance with the manufacturer's instructions, reflectors shall be fixed to the sides to increase visibility during night and the terminal sections of these moveable barriers shall be designed to alternate head-on impacts of at least *NCHRP Report 350* TL-1 or *EN1317* Containment Level N1. The displacement width of the barrier shall not exceed the available safe width to the edge of the construction work area. *TD Sections B1502 and B1503* (SANRAL, 2008)

Miscellaneous

This section covers multiple other actions and measures that could improve workzone safety. For example travel information provided by mass media, required safety- and risk assessments and actions to be taken at none working hours.

Mass media

At short term diversion of a carriageway the public shall also be informed through the media of the planned closure 7 days in advance of the closure or diversion. *TD Section B1502* (SANRAL, 2008)

Non-working hours

During the non-working hours, or when construction is not taking place on a certain section of road all unnecessary obstructions to the traffic shall be removed and all signs no longer applicable to the situation shall be removed. Also ensure that all obstructions related to the contractor's activities are removed at the end of each work shift and that the roads are safe for the travelling public. Should the contractor park any of his vehicles within the road reserve at night, it shall be behind temporary barriers and it shall be properly illuminated and signposted to ensure safe passing by traffic. *TD Sections B1502 and B1503* (SANRAL, 2008)

Traffic safety officer

The traffic safety officer shall have a traffic safety vehicle and sufficient labour at his disposal 24 hours a day, including all prescribed non working days, and shall not be utilised for other duties. Furthermore the traffic safety vehicle shall be a truck with a capacity of 3 tons. The safety officer's vehicle and the traffic safety vehicle shall also be equipped with an amber coloured flashing light of the rotating parabolic reflector type with a minimum intensity of 100 W. The warning light shall be switched on at all times and the sign shall be displayed when the vehicle is used on site. Also the words TRAFFIC CONTROL shall be written on a warning sign in highly legible letters, not less than 150 mm high, and the sign shall be mounted on both the traffic safety officer's vehicle and the traffic safety vehicle at least 1.5 m above ground level. The traffic safety vehicle shall be equipped with a high visibility rear panel in accordance with the requirements of the SARTSM as well as a truck mounted attenuator complying with TL-2 criteria when tested in accordance with *NCHRP REPORT 350* or N1 criteria when tested in accordance with *EN1317*. *TD Section B1502* (SANRAL, 2008)

Personnel

The contractor shall ensure that all his personnel, excluding those who are permanently office bound, are equipped with reflective safety jackets and that these are worn at all times when working on or near to the travelled way. Any person found not wearing a reflective jacket under these circumstances shall be removed from the site until such time as he is in possession of and wearing a reflective jacket. Reflective safety jackets shall be kept in good condition and any jackets that are ineffective shall be immediately replaced by the contractor. *TD Section B1502* (SANRAL, 2008)

Non-personnel

The principal contractor shall be responsible for ensuring that non-employees entering the construction site, the surrounding community of the construction site and people passing the site are made aware of the dangers likely to arise from construction work as well as the precautionary measures to be observed to avoid or minimise those dangers. *TD Section E3* (SANRAL, 2008)

Risk assessment

Contractors entering into contracts with SANRAL shall comply with the Occupational Health and Safety (OH&S) Act, No. 85 of 1993. Every principal contractor performing construction work shall, before the commencement of any construction work or work associated with the a foresaid construction work and during such work, cause a risk assessment to be performed by a competent person, appointed in writing, and the risk assessment shall form part of the OH&S plan.

The risk assessment shall include the identification of the risks and hazards to which persons may be exposed, the analysis and evaluation of the risks and hazards identified. It shall include a documented plan of safe work procedures to mitigate, reduce or control the risks and hazards that have been identified. Finally the risk assessment shall include a monitoring plan and a review plan. The principal contractor shall develop a set of site-specific OH&S rules that shall be applied to regulate the OH&S aspects of the construction based on the results of the risk assessment. *TD Section E1 and E2* (SANRAL, 2008)

2.3 International Standards

In this section the part of the base for the assessment of workzone safety part extracted from international standards will be established. The documents used as sources for the international standards are the Dutch standards (RWS, 2005), SWOV research (SWOV , 2008) (Van Gent, 2007), European ARROWS research (ARROWS, 1999) and American NCHRP research (NCHRP, 2005). The information gathered from these documents is split into four different sections based on the ARROWS research program (ARROWS, 1999) being; Adjustment of road layout, Traffic information devices, traffic guidance and restraint equipment and miscellaneous. In this section reference will be made to the *EN1317* standard and the *NCHRP Report 350* requirements. More information about these standards can be found in section Appendix B.

Adjustment of road layout

This section will go into the changes made in the road layout and speed limit to be able to accommodate the workzone for the roadworks.

Lane layout and closures

Layout changes should be used as least as possible to ensure a minimal influence on the flow of traffic and therefore total closing of traffic lanes should also be avoided where possible (ARROWS, 1999). Ideally, lane transitions would be designed so as to reduce or eliminate uncomfortable deceleration as well as speed variance in the workzone (NCHRP, 2005). As soon as the construction work has been concluded or halted, the systems disrupting traffic should be removed immediately or rapidly or at least reduced. Speed limits, and in particular those imposed for the safety of those working in the workzone, should be removed by covering over the relevant signs or providing indication that these do not apply outside working hours. It is also important to hold ready alternative routes for use in case of severe disruptions in the region of a workzone for example as a result of an accident (ARROWS, 1999).

Speed

To keep a uniform speed it is necessary to adjust layout of the roadworks to comply with demands for a required speed. At multiple workzones close to each other the same speed limits should be used (RWS, 2005). Also at one workzone only one speed limit should be used. It is important to make sure the instated speed limit is justifiable so that the road users do not exceed it. Research shows that the lower a speed limit is, the more it is exceeded. A speed limit seems to be more acceptable and complied with when it is credible (RWS, 2005). The Dutch standard speed limit for passing roadworks at a freeway is 90 km/h. The limit will be brought down to 70 km/h if; directly next to de lanes there are workers behind cones, the minimal width of the lanes can't be met or there is a need to do so due to other obstructions. If a temporary lane is designed and workers are behind barriers the design of the lane should be focused on a design speed of 100km/h (RWS, 2005).

The implementation of measures to reduce speeds can consequently reduce the number of speed related crashes and improve workzone safety (NCHRP, 2005). Reducing the maximum speed is intended to ease the driving task. In addition it also reduces the risk of a crash and lessens its severity. There are different measures that can be used to ensure the travelling public obeys the altered speed limits. Signs showing the actual speeds compared to the allowed speed are an example but also (Rumble) strips on the road surface to attend travelling public to the fact they drive too fast (Van Gent, 2007). Also other supplementary measures like enforcement and dynamic speed information can be used to accomplish compliance. Dynamic speed information is a measure which is used to measure the actual speed of each individual vehicle and communicate it to the driver (feedback). Research has shown that this causes drivers to lower their speed (NCHRP, 2005) (SWOV , 2008) and create a more uniform speed (Van Gent, 2007). When signalling is present above the road, speeds can be differentiated between lanes or for time of day (NCHRP, 2005) (SWOV , 2008). The use of different speed limits

per lane or differences in speed limits at different times (depending on presence of workers) is also encouraged by the Dutch Ministry of Traffic (RWS, 2005).
When it comes to speed reduction measures at road works, the location of a device should be carefully decided (ARROWS, 1999). Therefore speed limit signs, feedback VMS, lane narrowing devices and other measures used to make drivers slow down should preferably be positioned before road users enter the transition zone.

Entrance and exit of construction area

Entries and exits to/from motorways should be considered carefully ensuring the least possible influencing of the flow of traffic possible. Therefore workzones should wherever possible be accessed from the outside and not via the road affected itself (ARROWS, 1999). However, guidelines should be provided if entering and exiting the workzone has to be done through the affected road. These guidelines should cover providing space for acceleration and deceleration of trucks as they enter and exit the workzone, as well as for provision of periodic interruption of traffic in at least one lane (NCHRP, 2005).

Traffic information systems

Since workzone conditions vary from typical roadway conditions, it is important to inform the driver of the desired actions and the correct path through the workzone. Traffic information devices signs, marking, lighting, VMS's, DRIP's, reflective clothing and flagmen (ARROWS, 1999) (Van Gent, 2007) are used to communicate with drivers in advance of and within workzones. It is critical that the devices are understandable and visible and provide useful information (NCHRP, 2005). Maximum possible safety for construction personnel and road users is accomplished through these measures. This section will focus on these traffic information systems.

Traffic signs

Acceptance of drivers can more effectively be achieved by designing safety measures that are easily detectable and visible, as well as by the use of traffic signs, markings and closure devices that are in proper condition. A fundamental principle is to use as few traffic signs as possible but as many as necessary (ARROWS, 1999). Generally the aims of regulations, guidelines, etc. give the minimum needed signalisation on a road workzone to inform, give the way and guide road users through the workzone. A good use of signing to ensure the best possible safety of road users and road workers consists of three things. The first is effectiveness. According to drivers' self-reporting, their speed behaviour at work sites varies dependent on the road signs presented (ARROWS, 1999). The need for numerous traffic information devices in workzones, combined with existing signs, background clutter created by advertising signs and street lighting often makes it difficult to select and locate temporary traffic information devices. This can impose a high workload on drivers. Therefore where sign density is higher, temporary signs need to fit in with existing traffic control and cannot block or be blocked by other devices (NCHRP, 2005). The second thing that should be accomplished is coherence: signing must be adapted before the roadworks begin and should always be up to date so it can never give wrong or non-adapted information (ARROWS, 1999). The last focus point for signing is clarity: guiding road users and helping them to modify and adapt their behaviour to the situation requires some easy-reading and trusting signs. For the meaning of a sign to be clear to the road user it should be visible. Traffic signs should be well maintained and visible in both daytime and night-time conditions. Increased visibility of signs provides more information to drivers at a greater distance, and this is especially important at night. Furthermore increased sign spacing on high-speed roadways allows more time for road users to process the information on the signs and to prepare for the required manoeuvre (NCHRP, 2005).

Warning devices

To reduce the frequency and/or severity of workzone accidents a variable message sign (VMS) could be used to warn drivers to slow down (ARROWS, 1999). The VMS should be able to show 3 to 5 lines of text (8 to 10 characters) and it should also be able to display signs. The colour of the light should be white or yellow. Flashing arrow signs also guide traffic (Van Gent, 2007). Visibility of traffic information devices can be limited by poor retro reflectivity, obstructions, sight distance, weather conditions, wear, and other factors. Lack of visibility of traffic information devices can contribute to crashes in workzones. Maintenance of traffic information devices is important to the visibility of the devices. If visibility of traffic information devices is considered to be a potential factor in crashes that have occurred, field reviews may be regularly performed, especially at night, to determine if part of a device's message is obscured, obliterated, or blocked, as well as to check the retro-reflectivity of the device. Providing adequate visibility of traffic information devices aids in travelling public's advance perception of the travel path through the workzone (NCHRP, 2005). For better visibility the traffic information systems should be used in combination with a yellow and black striped reflective frame. The travelling public should be able to see the workzone when it approaches it. Therefore it is necessary to light the workzone so the travelling public can react to signs and instructions adequately (RWS, 2005). To achieve this artificial lighting and warning light should be used (NCHRP, 2005). If a workzone is designed in a proper way good visibility of all parts of the barricades used is sufficient (RWS, 2005). Rumblestrips can also be used to make sure the travelling public is made aware of a lane change and has enough time to do so in time. Rumblestrips are three strips with reflectors attached to the road that are supposed to warn travelling public, when seen or driven over, that a lane change is coming up. If they are placed at approximately 150m before the end of a lane they have a positive effect on safety (Van Gent, 2007). Advance warning vehicles can be used to alert drivers to the presence of a workzone**.** These advance warning vehicles should be equipped with warning lights, such as rotating beacons (NCHRP, 2005). It is well known that pulsing lights can give an illusion of motion. The results of a study test in a virtual environment (driving simulator) illustrate that the combination of colour, direction, and speed of the light pulses is important, and strongly influence the effect on speed (ARROWS, 1999). Though to improve safety it is important that if used these lights do not distract road users.

Markings

Temporary markings can be applied by paint, marking tape, prefabricated marking material, road surface reflectors or marking elements (RWS, 2005) and should be well maintained, easily understandable and visible to road users in both daytime and night-time conditions. Therefore highly reflective temporary pavement markings should be installed to delineate intended travel paths for increased visibility of markings provides more information to drivers at a greater distance. When the paths change, the temporary and permanent markings that are present for a previous stage need to be removed so that the driver has a clear definition of the currently desired path. Construction and maintenance may be done in stages so that vehicles are directed over different paths at various stages of work (NCHRP, 2005). Closely-placed raised pavement markings were observed to provide efficient guidance and a safe driving environment at road works and were therefore recommended to supplement to existing pavement striping. Behavioural adaptation also occurs when closely spaced raised pavement markings supplement ordinary markings (ARROWS, 1999).

Flagmen

In the United States flagmen are used in additional warning measure. Flagmen are people who wear conspicuous clothing and use a flag to warn road users of roadworks coming up (SWOV , 2008). The location of the flagman should provide as much sight distance from drivers to the flagmen as possible. The flagger should be far enough upstream of work space to allow motorists to respond to the flagger commands before reaching the work area. With this in mind, flagmen should be placed as close to the work area as possible to minimize delay in one-lane sections, which will help reduce the risk of congestion-related crashes (NCHRP, 2005).

Traffic guidance and restraint equipment

This section will give information on guidance and restraint systems like delineators and barriers. All these systems should comply with either the European *EN1317* standard or the American *NCHRP Report 350* requirements. Therefore in section 2.4 an explanation on these standards will be given.

Barricades like cones, delineators and barriers all have the purpose of marking out the workzone. Besides that they help to guide traffic through the roadworks area and reduce workzone intrusions (Van Gent, 2007). Other methods for reducing work space intrusions include: shadow vehicles with or without truck-mounted attenuators or arrestor nets, and vehicle arrestor barriers (NCHRP, 2005).

Channelization devices

Channelizing devices can be used to separate a work area from traffic. This does not, however, provide a physical barrier between the traffic lanes and the work area. Reducing the spacing of the devices provides additional positive guidance for drivers. Wider gaps in devices can be used to allow work vehicles to enter and exit the workzone, this should however only be done in compliance with the regulations for entering and exiting a workzone. Increasing the size of channelizing devices and decreasing the spacing of channelizing devices helps improving the visibility. Visibility may also be affected by degradation of the reflectivity of the device, the interference of physical objects, atmospheric conditions and darkness (NCHRP, 2005). Based on relatively weak driving behaviour and methodology, steady-burn lights are recommended to be excluded as delineation devices. Delineators can be used to separate the workzone from the traffic. A delineator consists of a crash friendly rectangular shield (max 1,25 m high and surface of about 0,25m2) covered with a red and white striped reflective print. It should be mounted on a weighted foot so it won't fall over (RWS, 2005). In some cases traffic cones can be used instead of delineators. For example centreline cones may be placed upstream of a flagman to alert drivers to the presence of a flagman in the roadway (NYSDOT, 2005)(NCHRP, 2005). A traffic cone consists of a cone shape top and a bottom plat that is designed in such a way that it cannot roll away when it falls over. The cone should be fluorescent orange and the height of a cone should be around 0,70 m (RWS, 2005).

Barriers

Barriers do fulfil two major functions: being the separation of contra flowing traffic and shielding the workzone from the traffic. In the Netherlands the minimal requirements are T3 (*EN1317*) which is a low angle containment level (RWS, 2005). To assure protection ability at the beginning of a series of barriers it is necessary to attach the barrier to a permanent structure or to an obstacle protection unit (RWS, 2005). Positive protection is defined as a device that contains and redirects vehicles in accordance with *NCHRP Report 350*, thereby preventing vehicles from intruding into the work space. Providing separation between the traffic and the work space, while not always achievable, has the potential to reduce crash frequency and severity for both workers and road users. (NCHRP, 2005). Providing physical barriers that separate traffic in the active lanes from the transition area, workzone, and/or buffer area is the cornerstone in positive protection. In nearly all cases, such barriers eliminate the possibility for intrusion into the respective workzone areas. Portable concrete barriers are the preferred barriers for such protection (NCHRP, 2005). To make sure barriers are visible to travelling public they should be supplied with barrier markings. These markings should be of a reflective kind. This to assure travelling public can see the barriers in time and change the driving style accordingly. It is important the markings are highly visible but do not distract the travelling public (RWS, 2005).

Physical barriers to protect workers from traffic works well against the penetration of the workzone but it increases the risk of a collision with a good chance of a vehicle ending up on the carriageway again or even at the opposite direction. Physical barriers should therefore only be used to prevent an even greater danger/risk (Van Gent, 2007).

To make sure a barrier will function properly it is important to evaluate whether the type of barrier is appropriate, whether the barrier meets the *EN1317* standard (RWS, 2005) or the *NCHRP Report 350* (NCHRP, 2005) requirements and is installed correctly, whether the barrier is in good condition, whether flared end treatments or impact attenuators are necessary, whether the barrier is delineated appropriately, whether adequate clear zone is available, and whether other roadside features such as slopes and unprotected fixed objects present safety hazards.

To prove the effectiveness of a vehicle restraint system it has to be tested according to the European *EN1317* standard or the American *NCHRP Report 350* requirements. In Appendix B some of the basic criteria in these standards and requirements will be explained. In Appendix F (Highway Agency, 2009) relevant sections of a list of US (FHWA, 2009) and European (Highway Agency, 2009) approved systems is added. Product information of the DeltaBloc barriers can be found in Appendix G and product information on the SANRAL barriers can be found their website (SANRAL, 2009) and could not be added as an appendix due to copyright issues.

Crash Absorbers

For crash absorbers used on a road with average speed of over 70 km/h the minimum requirement for safety is TL2 compared to the American *NCHRP Report 350*. They should be installed conform suppliers instructions mounted to a compatible vehicle or the object they should protect. An obstacle protector is to be designed to protect the beginning of a temporary barrier or fixed permanent objects at the workzone. It should be able to absorb head on crashes as well as guide vehicles with a sideways collision (RWS, 2005). These crash absorbers are only there to protect workers and materials (Van Gent, 2007). Furthermore impact attenuators reduce the risk of crashes and in addition lessen their severity.

Miscellaneous

This section covers multiple other actions that could improve workzone safety. For example travel information provided by mass media, required safety assessments and actions to be taken at none working hours and other government regulations.

Mass media

A citizens band radio channel broadcasting advisory messages could be used. A survey showed that a majority of truckers, whom the system targets, hear the message and think it is a worthwhile method of communicating. A highway advisory radio broadcasts advisory messages to drivers. A sign (dynamic or fixed message) informs drivers of the correct radio station, and messages regarding traffic delays, detours, road closures, and other travel conditions in the area can be broadcasted (NCHRP, 2005). The behavioural effects of a radio campaign among all truck drivers in Sweden were studied at a specific construction work site exposing drivers to lane narrowing. Almost all interviewed truck drivers judged the campaign as useful (ARROWS, 1999).

Traffic safety officer

It is important to follow up with contractors to make sure traffic safety officers are being used on projects where this is recommended or required. It may be desirable to have more than one traffic safety officer, possibly at least one on the contractor's staff and one from the highway agency staff, to be able to monitor more of the time when the workzone is active. The recent FHWA rule on workzone safety and mobility requires contractors and highway agencies to designate a trained person to be responsible for "implementing a transportation management plan and other safety and mobility aspects of the project (NCHRP, 2005). The person responsible for the safety of a workzone must be prepared to think about the individual problem and be prepared to make available what is optimally required for the drivers and other travellers; unfortunately, practical experience shows that this will only be achieved when appropriately strict checks are carried out and appropriate sanctions threatened. Obviously, the promotion of measures to ensure that the relevant contractors understand the safety aspects and feel responsible for these is an important task in connection with workzones on motorways and other roads (ARROWS, 1999).

Personnel

Visibility of workers is also a key issue in workzone safety (NCHRP, 2005) so measures like reflective clothing are there to point out the road workers to the travelling public (Van Gent, 2007) and should always be worn by all personnel working at workzones which are open on the traffic side (ARROWS, 1999). Being visible is important, not only for flagmen and other personnel directly exposed to traffic, but also for workers who are exposed to construction traffic in the work area. The visibility of vehicles and equipment is also a key element of workzone safety. And work vehicles should be well maintained and visible in both daytime and night-time conditions. Use more visible paint colours, or retro-reflective materials or backup alarms to increase visibility of work vehicles so it will provide road users with more warning that vehicles either are present or may be entering the traffic lanes (NCHRP, 2005).

3. Workzone Safety

3.1 Checklist

To explain the use of one checklist for both local contract requirements and international standards instead of two separate checklists a comparison on those standards covered in the previous chapter will be made. The bottom-line is that South African standards and European and American standard are not that different. Because the contract requirements for the GFIP are based on the European and American standards they are very much alike. Aside from different laws and regulations on signs and markings and different rules on for example speed limits the differences are very small. Therefore it is acceptable to have a single checklist to assess GFIP workzones at both local contract requirements and international standards.

To assemble the checklist all criteria from both the contract requirements and the international standards have been gathered. This resulted in the workzone safety criteria listed in the tables below. Table 1 contains criteria on adjustment of road layout, Table 2 criteria on traffic information systems, Table 3 criteria on traffic guidance and restraint systems and Table 4 shows criteria affecting miscellaneous items. The full checklist can be found in appendix C

ADJUSTMENT OF ROAD LAYOUT

Workzone layout	The dimensions of the information area are sufficient
	The dimensions of the transition area are sufficient
	The dimensions of the buffer area are sufficient
	The dimensions of the termination area are sufficient
	There are persons or vehicles in buffer area
	Lane diversion route is clear to travelling public
	The minimum amount of lanes have been used
	Flow of traffic is influenced as little as possible
Closures	The workzone is closed off properly
	Working vehicles and plant are properly protected
Speed	The speed limit is conform standards
	The speed limit is introduced in the right steps
	Speed reducing measures have been used accordingly
	Speed limit is the same through the entire workzone
Entrance/exit	Entrances are conform contract requirements
	Exits are conform contract requirements
	Entrance and exit possible from outside affected road
	Space is created to allow construction vehicles to accelerate into the flowing traffic

Table 1: Workzone safety criteria on adjustment of road layout

TRAFFIC INFORMATION SYSTEMS

Signs	The correct signs have been used
	Signs are visible
	Signs are placed in the correct place
	The message of the signs is clear
	Unnecessary signs have been removed
Warning devices	Flicker lights are in the right place
	Flicker lights are highly visible
	Illuminated arrow board is in the right place
	Illuminated arrow board is highly visible
	Variable message sign has been used accordingly
	VMS is highly visible
	The message on the VMS is clear
Markings	Temporary marking is clearly visible
	Temporary markings has been applied when necessary
	Old markings have been removed were necessary
Flagmen	Flagmen are in the right place
	Flagmen have the right equipment
	are highly visible

Table 2: Workzone safety criteria on traffic information systems

TRAFFIC GUIDANCE AND RESTRAINT SYSTEMS

Cones	The used cones are designed properly
	Cones have been lined up properly
Delineators	Delineation has been placed straight
	Delineators are properly supported by sandbags
	The used delineators comply to standards
	Delineators are properly spaced according to standards
	Broken delineators have been replaced
	Delineators are highly visible
	Delineators are in good state
Barriers	Barriers have been used to separate traffic from workzone
	Barriers have been used to separate contra flowing traffic
	The used barriers have been installed properly
	The used barriers are delineated properly
	The used barriers comply with requirements
	Reflectors have been used to make barriers more visible
	No broken or damaged barriers are found at site
Crash absorbers	Objects and barrier ends are protected by crash absorbers
	Crash absorbers comply with requirements

Table 3: Workzone safety criteria on traffic guidance and restraint systems

MISCELLANEOUS	
TS officer	traffic safety officer is present at site
	traffic safety vehicle is present at site
	traffic safety vehicle meets regulations
	traffic safety officer has a vehicle complying with regulations
Personnel	personnel is wearing reflective clothing
	all vehicles are equipped with adequate lights
Non-personnel	non-personnel is issued with required reflective clothing
	non-personnel is made aware of dangers
Risk assessment	risk assessment has been executed
	site specific OH&S rules are instated

Table 4: Workzone safety criteria on miscellaneous items

3.2 Results workzone safety assessment

In this chapter an overview of the results of the GFIP workzone safety assessment will be given. The full site inspection reports can be found in Appendix D and the filled in checklists in Appendix E. 10 worksites have been visited. At site D the researcher has been showed around by the Traffic Safety Officers of the subsections D1 and D2. Because of a shortage of time the other sites were only assessed from the car. To get a better view on overall workzone safety it would be better to do surveys in bad weather conditions and at night. Some warning devices are only functional at night and visibility and reflectivity is a much bigger issue in bad conditions and at night.

Adjustment of road layout

In this section the results regarding the adjustment of road layout will be shown. An explanation will be given on how well changes in lane layout and speed were done and on how work vehicles could enter and exit the workzone.

Lane layout

The information area is the first and one of the most important safety areas at a workzone. It is important to inform the road users of the road works ahead. At all the visited work packages the dimensions of the information area were sufficient. The transition area was sufficient most of the visited sites, at one site the transition area was much too short and at one other site the transition area was a bit short. At all but one of the sites the buffer area was of the right dimensions. At one site the buffer area was too small. A problem in the buffer area at one of the sites was that there were both persons and vehicles in the safety area. This caused a safety liability. All workzones should be ended with a termination area. In this area the original state of the road will be restored. At all but one site the termination area was of the right dimensions.

Figure 3: Unprotected workzone

Closures

For the obvious safety reasons the workzone should be closed off from traffic properly. This means that vehicles can't penetrate the workzone and that all plant and vehicles that are on the road are protected. At multiple sites this was not done properly. At one of the sites there were holes and piles of soil at the side of the road (Figure 3), at another site there were 2m deep holes that were not protected. These holes were meant for the foundations of light posts. The light posts were lying unprotected next to the holes (Figure 4). This caused a very dangerous situation where if a vehicle would hit the light post it would be speared. At another site the assembly of a guardrail was taking place, this was not happening behind protection also warning vehicles were missing.

Figure 4: Lightpost at roadside

At multiple times slow construction vehicles were standing or driving in traffic without protective or warning vehicles (Figure 5b and 5c). A lot of the times there were safety vehicles with TMS's at site but the TMA wasn't in use. At one site a generator was standing at an off ramp without any protection (Figure 5a).

Figure 5: Unprotected plant

Speed

Setting speedlimits and introducing them in the right steps is a very important aspect in workzone safety. At all the sites visited the speedlimits were according to the requirements. The steps in which these speed limits are introduced were also according to the standards. Nevertheless the road users do not keep to the speed limits. For example when the safety vehicle was driving in a 60km/h zone in a workzone at about 80 km/h in the middle lane the traffic was "flying" past it at both sides. At none of the workzones speed reducing measures were used. A safety officer at one of the sites also said law enforcement in the workzones is not allowed and that this had been published in the newspapers. Another safety officer said SANRAL offered traffic control to pay for equipment and extra hours etc. So they would keep a strict control on speed in workzones. This had no effect at all, there is still no traffic enforcement at workzones. Without people keeping to the speed limits a lot of dangerous situations occur in the workzone.

Entrance and exit of construction area

At a big part of the worksites the entrances and exits to the construction area were minimised and according to standards. At a lot of other worksites the entrances and exits were more than the standards and at two of them the exits and entrances were all over the place creating many openings in the protection and gaps where the workzone could very easily be penetrated. At all but one worksite construction vehicles exiting the workzone could accelerate into the traffic. At almost none of the sites entering and leaving the workzone was possible from outside the affected road. This was mainly because a lot of the work was in the median or between the road and a sound barrier.

Traffic information systems

In this section the systems for traffic information will be assessed, an explanation will be given on how well signing, warning devices, markings and flagmen were conducted.

Traffic signs

At most workzones the signing was according to the requirements. The message of the signs was clear and visible and the signs were placed correctly. The correct signs had been used and unnecessary signs were removed from site at most workzones. At one site a sign had fallen over and therefore wasn't very visible (Figure 6). At another sites signs that were not in use at that moment were made invisible (Figure 7) the problem that because this was not done properly, these signs made the message unclear and caused major confusion at this site. At some of the sites signs were very dirty and therefore not very reflective, at time of the inspection, during the day, this did not really cause a problem, but at night reflection is one of the most important aspects in visibility of signs.

Figure 6: Sign fallen over

Warning devices

To make travelling public more alert to a workzone a lot of different warning devices can and should be used at the workzones. At the workzones of the GFIP there was a lot of difference in how well warning devices were used. At a lot of sites the flickering warning lights were missing. At some sites the flashing arrow light was not flashing, at another site it was pointing in the wrong direction. Nevertheless at a reasonable part of the workzones the warning devices were used accordingly and in the right combinations. A lot of them had a flashing arrow board and flicker lights to indicate closures and lane diversions. Almost all sites had a VMS at the beginning of site warning for the roadworks and giving instructions.

Figure 7: Sign made invisible

Markings

The quality of the markings at different sites was not very similar, a lot of sites did not have clear temporary markings (Figure 8c), and at a lot of sites the old marking wasn't removed properly (Figure 8a and 8b). At some of the sites (temporary) markings were very clear and visible (Figure 8d).

Figure 8: Different states of marking

Flagmen
Flagmen were used at the majority of the sites but in a lot of cases there was something not right in the way they were placed or were doing their jobs. Visibility of flagmen and flags could have been better, a lot of the reflective material was dirty and therefore not as reflective as it should have been. A lot of flagmen were not using the right flagging techniques and a lot of them were not even flagging at all. Also at a lot of sites placing of flagmen was not according to the requirements or not enough flagmen were used.

Traffic guidance and restraint equipment
In this section safety equipment for vehicle guidance and restraint will be explained. Results for delineation devices, barriers and crash absorbers are shown.

Channelization devices
At most sites cones and delineators were used for delineation. The cones and delineators that were used complied with the regulations. A big problem at most of the sites was that a lot of delineators were damaged (Figure 9), trucks seem to make a game out of running over as much delineators as possible and that makes it almost impossible for a contractor to keep replacing the broken ones. Also a lot of delineators were not supported properly with sandbags, this means they fall over when a truck drives past or when there are hard winds. If sandbags are supporting the delineator a lot of the times they block part of the reflective section of the delineator, this makes the delineator less visible. A solution to this problem is to use taller delineators so they are visible in combination with the sandbags supporting them. The alignment of delineators could have been a lot better, most of the time it was not straight. The spacing of the delineators was good at some of the sites but at other sites the delineators were too far, allowing a big gap in the delineation.

Figure 9: Damaged delineators

Barriers
Compared to the other factors in workzone safety for this, and the next section it is a lot easier to say if a system complies to the requirements or not. This is because a system can be tested and therefore there should not be a grey area. A problem is that for the testing of barriers and crash absorbers you need a test facility. In South Africa there is no such facility. So we know that all tested safety systems come from outside South Africa or have been tested there. A list of FHWA approved systems, tested according to NCHRP Report 350, and a list of British HA approved systems, tested to EN 1317 requirements, is added in Appendix F.

At the GFIP three kinds of temporary concrete barriers have been used. The SANRAL designed single sided barrier that can be turned in to a permanent barrier, the SANRAL designed temporary barrier and the European designed DeltaBloc barrier. The single sided barrier has not been tested or approved as a temporary barrier. The design for the SANRAL temporary barrier has been based on three American made and tested barriers, the Pennsylvania F shape, Georgia 3M pinned TCB barrier the Rockingham 3,8M pinned F shape TCB. NCHRP Report 350 Test level for these systems is TL3 where SANRAL contract requirements ask for TL4 or higher. Therefore these barriers do not comply and that is actually a seriously contradicting situation that the SANRAL designed and produced barriers do not comply with their own requirements. The DeltaBloc barriers have been tested to the EN1317 standards and comply to a test level H1, this meets the SANRAL required level and therefore these DeltaBloc systems comply, product information on these barriers can be found in Appendix G.
But before being able to say that a system complies or not it's important to look at the installation and state of different barrier systems. Because a system only complies with the approved test level when it is installed according to manufacturer's standards. At the worksites if the GFIP a lot of barriers were not installed properly and therefore not complying with the contract requirements. At a lot of sites several barriers were not joined (Figure 10) or gaps in the barrier systems were found, different kinds of barrier systems were not joined together as well. Also quite a lot of barriers were severely damaged (Figure 11), this damage lowers the system's ability to redirect a vehicle.

Figure 10: Non joined barrier systems

Figure 11: Cracked barrier system

When looking at actual workzone safety it can be concluded that barrier systems, when installed accordingly, do prevent a lot of workzone penetrations by vehicles. A lot of barrier impacts have been seen at site and at most times the vehicle did not penetrate the workzone. This regards both SANRAL (Figure 12b and 12c) and DeltaBloc barrier systems (Figure 12a). A big difference between the both systems is that the SANRAL system moves quite far at impact (Figure 12b and 12c) where the DeltaBloc system hardly moves at all (Figure 12a). Another big problem is that in workzones where contra-flow occurs the delineation of the barriers is not restored and this causes severe danger to traffic in both directions.

Figure 12: Impacted barrier systems

Crash Absorbers

Barrier ends and objects should be protected with crash absorbers or attenuators. At most sites sandbags (Figure 14b), plastic (water filled) barriers or plastic (water filled) watertanks (Figure 14a) were used as a crash absorber, but in a lot of cases barrier ends were not protected (Figure 13). In one situation an approved crash absorber was used. But the installation of this device was not according to standards; it should have been anchored to the surface which was not the case (Figure 15).

Figure 13: Unprotected barrier ends

Figure 14: Watertank and sandbags used as crash absorber

Figure 15: Crash absorber not anchored

Miscellaneous

Traffic Safety officer

At the sites were the researcher was shown around by the contractor the TSO was present at site and so were the required safety vehicles (Figure 16). At other sites safety vehicles have been spotted. At one site the TSO left his vehicle without using reflective clothing and at another site the safety vehicle was used for transport purposes.

Figure 16: Traffic safety vehicle

Personnel

All personnel was wearing reflective clothing at all sites. The biggest problem is that, because they are performing roadworks, their clothing was very dirty and therefore not as reflective as it should have been.

Risk Assessment

The researcher has visited some site offices and at these offices risk assessment and site specific OH&S rules were present.

4. Conclusions

The goal of this research project stated in the beginning of this report is as follows:

To get knowledge of how workzone safety measures are being implemented at the Gauteng Freeway Improvement Project (GFIP), to see how this workzone safety stands according to local contract requirements and international standard and to point out where it needs improvement.

To see how well this goal has been reached the research questions have to be answered. First a look will be taken at the local contract requirements. The main sources for local contract requirements are the SANRAL tender documents. These documents specify to the detail how every aspect of the GFIP should be executed. Workzone safety is an important part of these tender documents. The level of these requirements is quite high, a reference is made to the European EN1317 standard and American NCHRP Report 350 requirements. The SANRAL requirements ask for a fairly high test level of these standards.

To have a comparison for the level of the contract requirements a survey has been made of "western" standards for workzone safety. The documents used as sources for the international standards are the Dutch standards (RWS, 2005), SWOV research (SWOV , 2008) (Van Gent, 2007), European ARROWS research (ARROWS, 1999) and American NCHRP research (NCHRP, 2005).

An interesting conclusion can be made from the comparison between the local contract requirements and these international standards for workzone safety; there is not much difference in what is required for a safe workzone. Both require high performance safety measures at workzones to make them safe.

So how do the GFIP workzones stand compared to the safety standard? This will be explained by the four categories the different safety aspects have been divided in for the literature study.

The first safety aspect is the adjustment of road layout. This aspect focuses at traffic accommodation. At the different workzones of the GFIP this safety aspect was reasonably well looked after. The dimensions of the safety areas were according to standards, speed limits were introduced properly and also according to standards and at most sites the entrances and exits to and from the workzone were not causing dangerous situations. Still in this aspect speed is the biggest problem because although the speed limits are according to the standards the road users do not comply tot the speed limits causing dangerous situations throughout the workzones. No speed limits or law enforcements were found at site so there was no real force to keep road users from speeding.

Secondly the traffic information devices were assessed. This includes signs, warning devices, markings and flagmen. In this category a lot of standards and requirements couldn't be met. Signing was according to the standards at most of the sites but a reasonable amount of sites could not meet the standards for warning devices. A lot of the sites had badly visible markings and badly removed old markings. At one site no temporary marking had been applied. Flagmen were also a problem because although at most sites the flagmen were present they did not improve the awareness because they were often not as visible as they should have been and they were also not flagging a lot of the times or flagging in the wrong techniques.

The third category in safety aspects are vehicle guidance and restraint systems. This category is more black and white than the others because compliance of these systems can be measured and therefore there is no grey area. This category contains delineation devices, barriers and crash absorbers. Delineation is a major issue at the GFIP. The setup of delineation happens only partially according to standards; spacing and alignment is not always as it should be.

But the biggest problems are broken and damaged delineation devices. Trucks seem to make a game out of running them over therefore a contractor has to replace a lot of delineators. Also the stabilisation of the delineators isn't as it should be so a lot of delineators are blown over by the wind.

Barriers are the second major part of this category. A vehicle restraint system or barrier has, according to the contract requirements, to comply with NCHRP Report 350 TL4 or the EN1317 H1 test level. To know if a system is compliant it has to be tested at a special facility. South Africa does not have such a test facility so used barrier systems either have to come from other countries or have to be tested there. Of the 3 types of used temporary concrete barrier systems at the GFIP two have been tested. The DeltaBloc barrier systems have been designed and tested to the EN1317 and comply with Test level H1. The SANRAL designed F-shape barrier is designed after the example of three American barrier types that comply with NCHRP 350 TL3. The SANRAL designed single side barrier is actually designed to be casted in for permanent use. Of these three types of barrier systems only the DeltaBloc complies with the SANRAL contract requirement. This is contradicting because SANRAL designs and issues barriers that do not comply with their own standards.

An even bigger problem than the compliance of these barrier systems is the installation. These systems are only effective as they are installed properly because the different barriers work together to absorb kinetic energy at an impact. If barriers for example are not joined properly the effect of the system is gone and the results at impact will not be safe. At a lot of the sites the installation of the different systems was not according to manufacturers standards. This caused a major safety problem. There were installation had been executed according to standards the positive effects could be seen. A lot of impacted locations have been spotted during site inspections and where the installation was good penetration of the workzone hardly occurred, even with non complying barrier systems.

The last component of this category is the crash absorbers. A lot of non complying systems like, water filled plastic barriers, filled plastic water tanks and heaps of sandbags were used. These do not comply with international standards for crash absorbers. One complying crash absorbing system was found at site but this system was not installed properly and therefore not safe.

The last category in the workzone safety assessment is miscellaneous; things like risk assessment, traffic safety officers, safety vehicles, personnel and non-personnel are important to guarantee a safe workzone. At the two site offices that were visited risk assessments and site specific sets OH&S rules were found. Safety officers and required vehicles were also found at site. At one site a safety vehicle was used for transport purposes, and this contradicts directly with the SANRAL requirements. Not much can be said about how non-personnel at site is treated and made aware of the safety issues. All personnel at all sites was wearing reflective clothing according to standards but these clothes were often dirty from the work en this made the reflectivity a lot less. But besides these small points aspects in this category were executed pretty reasonably.

All together the workzone safety at the GFIP could be improved a lot, the main line is set out but the strictness of how the line is followed should have a boost. This way a lot of unsafe situations can be avoided.

5. Recommendation

An improvement in workzone safety at the GFIP and throughout South Africa has to consist of two major things:

Firstly contractor's compliance with the safety standards has to improve drastically. Only if the specified warning and safety systems are used a safe workzone can be created. Because workzones are very variable because the work is always on the move this compliance includes repeatedly checking the workzones. Making sure the workzone setup is according to standards, lane closures have been executed properly, delineation is according to standards and the workzone is closed of properly with complying barrier systems that are installed according to manufacturer's specifications. Experience in Europe shows that this result can only be accomplished if the situation is checked over and over again and if non-complying contractors are faced with the consequences.

Secondly the road user should stop treating the workzone as a normal section of highway. Speed limits need to be followed. There are two ways of reaching this goal; the first is to install speed reducing measures like speedbumps and rumblestrips. Traffic will be forced to slow down. The second way of achieving coherence with the rules is enforcing the rules. In Europe the consequences for violating of for example the speed limit at a workzone are much heavier than at a normal section of freeway. This way the road user will hopefully learn to keep the rules and help creating a safer workzone.

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