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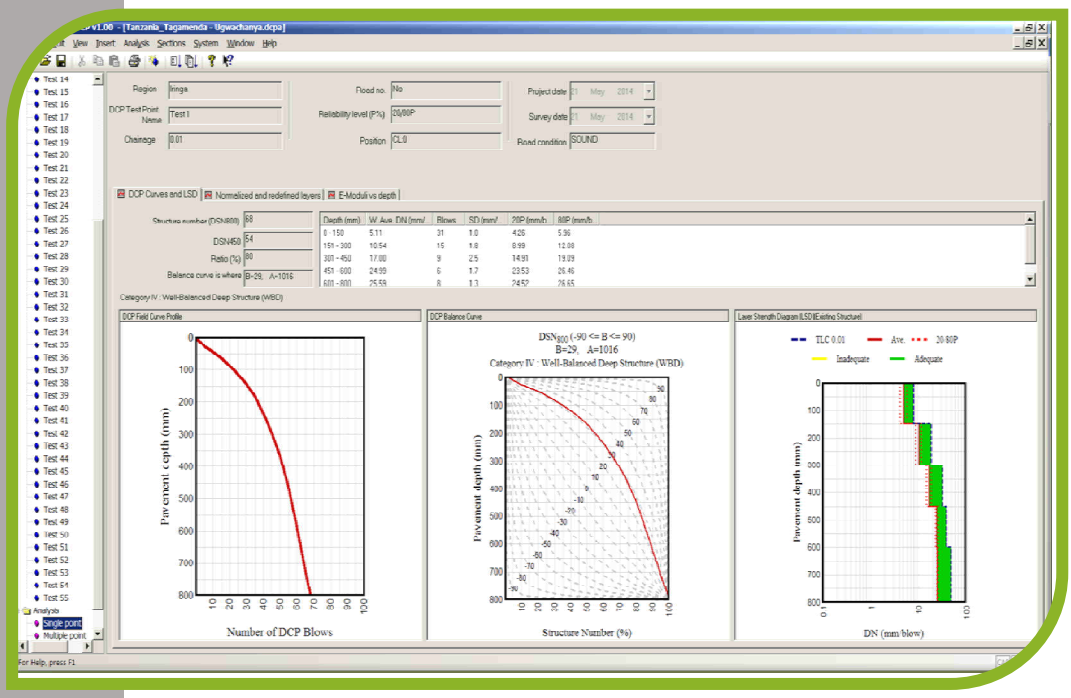
Improvements to the WinDCP software for Pavement Design of Low Volume Roads - Final Development report

Final Report



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CSIR Built Environment

AFCAP Project Reference Number GEN2023A

February 16, 2016

CSIR
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Cover Photo: AfCAP LVR DCP v1.00

Quality assurance and review table			
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Abstract

This final report describes the deliverables of Phase I of the project for improving the existing Dynamic Cone Penetrometer (DCP) WinDCP software for the purpose of use on Low Volume Roads (LVRs). The deliverables include a new AfCAP LVR-DCP v1.00 software product and software help file (SHF), which were defined during various discussions and two official workshops from the project team. Peer review resulted in a workable software product for the analyses of single or multiple point DCP analysis. In addition to the field DCP analysis module, a laboratory DCP module was also added. A user friendly software help file (SHF) is also included, intended to assist largely during use and training of the AfCAP LVR-DCP v1.00 software package.

Key words

Dynamic Cone Penetrometer (DCP), Low Volume Roads (LVR), LVR-DCP, DCP-DN Design method, WinDCP, software package, Layer, $DSN_{800,}$ DSN_{450}

Acronyms, Units and Currencies

$	United States Dollar (US$ 1.00 ≈ provide conversion to local currencies)
ADB	Asian Development Bank
AfCAP	Africa Community Access Partnership
AsCAP	Asia Community Access Partnership
CSIR	Council for Scientific and Industrial Research
DCP	Dynamic Cone Penetrometer
DN	DCP penetration in mm/blow
DSN_{450}	Design Structural Number to 450 mm
DSN_{800}	Design Structural Number to 800 mm
GPS	Global positioning system
LVR	Low Volume Road
PRT	Peer Review Team
RECAP	Research for Community Access Partnership
RTM	Regional Technical Manager
SHF	Software Help File
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)

Contents

1 Executive summary

The advent of the DCP-DN method of pavement design has triggered a need to upgrade the CSIR WinDCP Ver 5.1 software (generally known as "WinDCP 5.1") to take account of relatively recent developments in low volume road technology. To this end, the South African Council for Scientific and Industrial Research (CSIR), under commission from AfCAP, has been tasked with the upgrading of the software and with the revision of the User Manual + Help File.

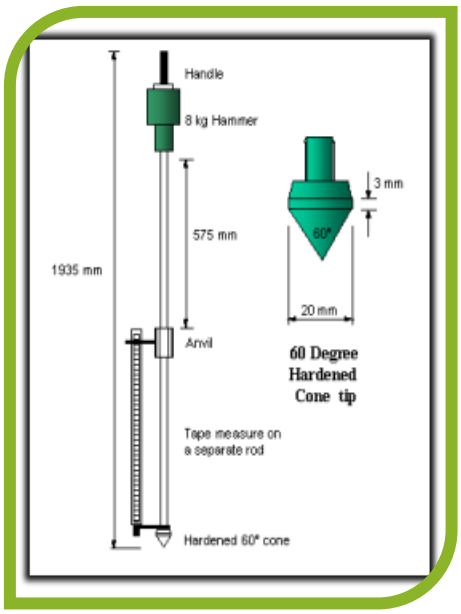
This report constitutes the final milestone deliverables (Phase I) of the project for improving the existing Dynamic Cone Penetrometer (DCP) WinDCP software for the purpose of use on Low Volume Roads (LVRs). The deliverables include a new AfCAP LVR-DCP v1.00 software product and software help file (SHF), which were defined during various discussions and two official workshops from the project team. AfCAP LVR-DCP v1.00 was developed with Microsoft Visual Studio C++. Peer review resulted in a workable software product for the analyses of single or multiple point DCP analysis. In addition to the field DCP analysis module, a laboratory DCP module was also added. A user friendly software help file (SHF) is also included, intended to assist largely during use and training of the AfCAP LVR-DCP v1.00 software package.

Phase I consisted of twenty one (21) items identified from industry which needed recoding and further development from the known WinDCP 5.1 software, which is widely available. A need existed to define and develop new DCP software specifically for use in the Low Volume Road (LVR) scenario, hence the development need for a new DCP software package under AfCAP contract managed by Cardno.

The final AfCAP LVR-DCP v1.00 software is solely based on the so called "DN" method, intentionally developed *without* empirical relationships, e.g. between DN and California Bearing Ratio (CBR), or any form of structural capacity predictions. Traffic Loading Classes (TLCs) were defined based on the concept of structural balance, providing for new pavement designs from 0.01 up to 1 million equivalent standard axles (ESALs).

2 Introduction

2.1 Background



The final milestone of deliverables (Phase I) of the project for improving the existing Dynamic Cone Penetrometer (DCP) WinDCP 5.1 software for the purpose of use on Low Volume Roads (LVRs) is summarised here. The WinDCP 5.1 software developed by Council for Scientific and Industrial Research (CSIR), South Africa, has been identified by practitioners as an appropriate tool for pavement design of low volume roads (LVR). In this regard, a number of training courses have been held in various countries for private sector consultants and government staff on the use of the DCP-DN Design Method and related software. It has, however, become apparent that the software needs to be upgraded to take account of relatively recent developments in low volume roads (LVR) technology that are not catered for in the current version of the software. In addition, the software needs to be made more user friendly to suit the needs of first-time users.

2.2 Approach and Methodology

In light of the above, AfCAP has commissioned CSIR to undertake the upgrading of the WinDCP software, for which various suggestions for improvement were first discussed by a number of practitioners at a meeting held at CSIR in August 2013. Since then, various improvements have been incorporated in the new WinDCP AfCAP software based on the DCP-DN method of pavement design.

A Peer Review Team (PRT) comprising practitioners and experts have been selected to participate in workshops as well as review of the improved versions of the software and software help file (SHF) as per various stages of development. The main purpose of the PRT was for reviewing the different stages of the WinDCP software upgrading project, as indicated in the Terms of Reference (ToR).

2.3 Development Stages and Workshops

As stated, AfCAP has also appointed a Peer Review Team (PRT), comprising practitioners with varied experience in the use of the WinDCP software, to review and comment on the improvements to it that were made CSIR. The review was undertaken in three stages as follows:

- **Stage 1:** PRT review and comments on June 2015 CSIR Progress Report based on partially completed Beta 1.01 version of the software (completed December 7, 2015).
- **Stage 2:** PRT review and comments on CSIR Draft Final Report based on test-run of the DCP-DN design procedure using the Beta v1.02 of the software (completed January 8, 2016).
- **Stage 3:** PRT review and comments of final version of software based on comments emanating from Stage 2, leading to a final meeting at CSIR (completed January 20, 2016).

In total three workshops were held during this assignment at the premises of the CSIR, Built Environment Unit. These with outcomes were:

1. **Initial Workshop 1:** August 26, 2013: Outcome given here in Annex A.
2. **Workshop 2:** December 07, 2015: Further development as given in report: WinDCP Upgrade Stage 1 Workshop Report.pdf by Pinard *et al.,* (2015);
3. **Workshop 3:** January 20, 2016: Final development for v1.00 of the software as given in WinDCP Upgrade Stage 2 Workshop Report.pdf by Pinard *et al.,* (2016a, b).

2.4 Deliverables

The deliverables include a new AfCAP LVR-DCP v1.00 software product and software help file (SHF), which was defined during various discussions and two official workshops from the project team, i.e. AfCAP LVR-DCP v1.00. AfCAP LVR-DCP v1.00 was developed with Microsoft Visual Studio C++. Peer review resulted in a workable software product for the analyses of single or multiple point DCP analysis. In addition to the field DCP analysis module, a laboratory DCP module was also added for the purpose of evaluating the DCP testing designed for laboratory use. A user friendly software help file (SHF) is in the software, intended to assist largely during use and training of the AfCAP LVR-DCP v1.00 software package.

During deliberations, a need for a "User Manual" was expressed by the PRT. CSIR is to initiate a draft document entitled "AFCAP Low Volume Road – User Manual v1.00" This draft document will be separate from the Software Help File (SHF), and should be based on a "step-by-step" procedure following a typical LVR DCP design procedure. In this case, the Malawi DCP manual will be used as a basis for developing the User Manual.

3 Development objective

The development objective of (Phase I) of the project for improving the existing Dynamic Cone Penetrometer (DCP) WinDCP 5.1 software was for the purpose of application on Low Volume Roads (LVRs). The deliverables include a new AfCAP LVR-DCP v1.00 software product and software help file (SHF), which was defined during various discussions and two official workshops from the project team.

Initially twenty one (21) items were defined during evaluating the existing WinDCP 5.1 software package on 26th August 2013 at CSIR, Pretoria. These items are given in the Annex (Outcome of WinDCP Software Mini-Workshop) of this report. Each of these items was addressed during development of the new DCP package. A further two "unscheduled" workshops were held at CSIR in order to shorten the implementation and final acceptance of the software. These were held on December 7th, 2015, January 8, 2016 and January 20, 2016. The following documents refer:

1. Pinard *et al.,* (2015). December 7th, 2015: WinDCP Upgrade Stage 1 Workshop Report.pdf;
2. Pinard *et al.,* (2016a). January 8, 2016: WinDCP Upgrade Stage 2 Report Rev 1.pdf;
3. Pinard *et al.,* (2016b). January 20, 2016 WinDCP Upgrade Stage 3 Workshop Report.pdf

4 Software coding environment

The existing DCP software WinDCP 5.1 was used as a basis from where the new AfCAP LVR-DCP software was developed. AfCAP LVR-DCP v1.00 was also developed with Microsoft Visual Studio C++. In general Object-oriented programming (OOP) was implemented to develop AfCAP LVR-DCP.

Note: Object-oriented programming (OOP) is a programming paradigm based on the concept of "objects", which are data structures that contain data, in the form of fields, often known as attributes; and code, in the form of procedures, often known as methods.

4.1 Software developing methodology

The incremental life cycle model was used to develop the AfCAP LVR-DCP v1.00 program. In incremental model the whole requirement is divided into various “builds”. Multiple development cycles take place here, making the life cycle a “waterfall cycle”. Cycles are divided up into smaller, more easily managed modules. Each module passes through the requirements, design, implementation and testing phases. A working version of software is produced during the first module, so you have working software early on during the software life cycle. This was one of the most important elements in the AfCAP LVR-DCP software build. Each subsequent release of the module adds function to the previous release. The process continues until a complete system is achieved. A total of one (1) alpha early development phase, and 5 versions of Beta development phases were developed and tested during this assignment. See Table 1 later.

4.2 Waterfall cycle

This is the most common and classic of life cycle models, also referred to as a linear-sequential life cycle model. In a waterfall model, each phase must be completed in its entirety before the next phase can begin. At the end of each phase, a review takes place to determine if the project is on the right path and whether or not to continue or discard the project. This was followed after each new requirement became clear. As a result several build dates were made of the standalone AfCAP LVR-DCP software.

4.3 AfCAP LVR-DCP Build Dates

The various versions of the software during development is summarised in Table 1. Both the dates as well as associated progress reports are listed.

Table 1. Different stages of AfCAP LVR-DCP (previously WinDCP AfCAP) softwares during this assignment.

Version	Build date	Progress Reports
WinDCP AFCAP Alpha v1.00	14/04/2015	WinDCP AFCAP Progress 31 March 2015.pptx (Internal use - CSIR)
WinDCP AFCAP Beta v1.00	26/06/2015	WinDCP AFCAP Progress 26 June 2015.pptx
WinDCP AFCAP Beta v1.01	09/09/2015	WinDCP AFCAP Progress 30 Sep 2015.pptx
WinDCP AFCAP Beta v1.02	13/11/2015	WinDCP AFCAP Beta ver1.02 report 13Nov2015.docx
WinDCP AFCAP Beta v1.03	26/11/2015	WinDCP AFCAP Progress 26 Nov 2015.pptx; WinDCP AFCAP Progress 30 Nov 2015.pptx
WinDCP AFCAP Beta v1.04	08/01/2016	No report
WinDCP AFCAP Beta v1.05	14/01/2016	WinDCP AFCAP Progress 15 Jan 2016.pptx
AfCAP LVR-DCP v1.00	05/02/2016	This report (pdf).

4.4 Installation

The installation for AfCAP LVR-DCP v1.00 was built with InstallShield and a CSIR authentication certificate was used to sign the installation. See Figure 1. After every change (or modification), the software needs to be installed before use in order to create the executable version, i.e. with typical extensions is *.exe".

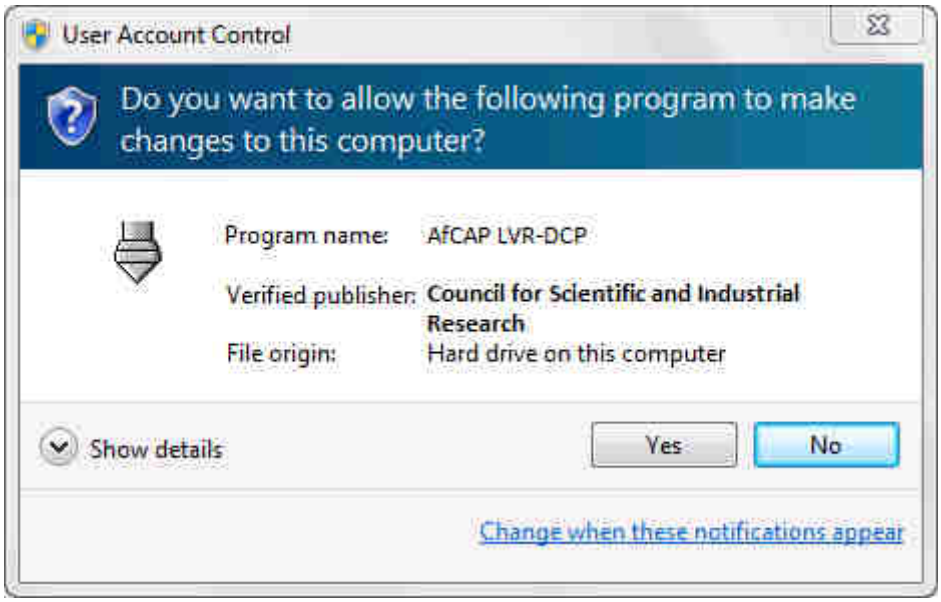


Figure 1. InstallShield

The "About DCP" after "AfCAP LVR-DCP v1.00 install" is given in Figure 2.

Figure 2. "About DCP" of current AfCAP LVR-DCP Package

4.5 Excel reports

A C# project was developed for importing and exporting projects and reports to Excel (.xlsx) format. A managed C++ Common Language Infrastructure (CLI) wrapper was created to link the C# Excel project into the AfCAP LVR-DCP program. Several such reports are available in the AfCAP LVR-DCP software.

5 Methodology

5.1 Main items coded

The following main items were coded:

1. Data and location of project date, field DCP Test data, including area, road width, moisture regime, etc;
2. DCP Test Data (DCP Test Points) management:
    a. Insert new data;
    b. Delete incorrect data;
    c. Rename test data file;
3. Arranging of data by name, date, chainage, size;
4. Data Analyses:
    a. Single data analysis;
    b. Multiple point analysis.
5. Laboratory DCP test data, project date, including area, borrow pit, stockpile, etc.,
6. Data import/export to Excel;
7. Generation and printing of Summary Reports;
8. Generation and printing of Detail Reports;
9. Save as Win DCP 5.1 file format (*.dat);
10. DCP System configuration:
    a. Single point analysis (Layers and percentile values);
    b. Multiple point analysis (Layers and percentile values);
11. Traffic Load Class (TLC) design curves configuration, including user defined curves.
12. Default layer thicknesses of 150 mm;
13. Report Options – see Figure 3 below.

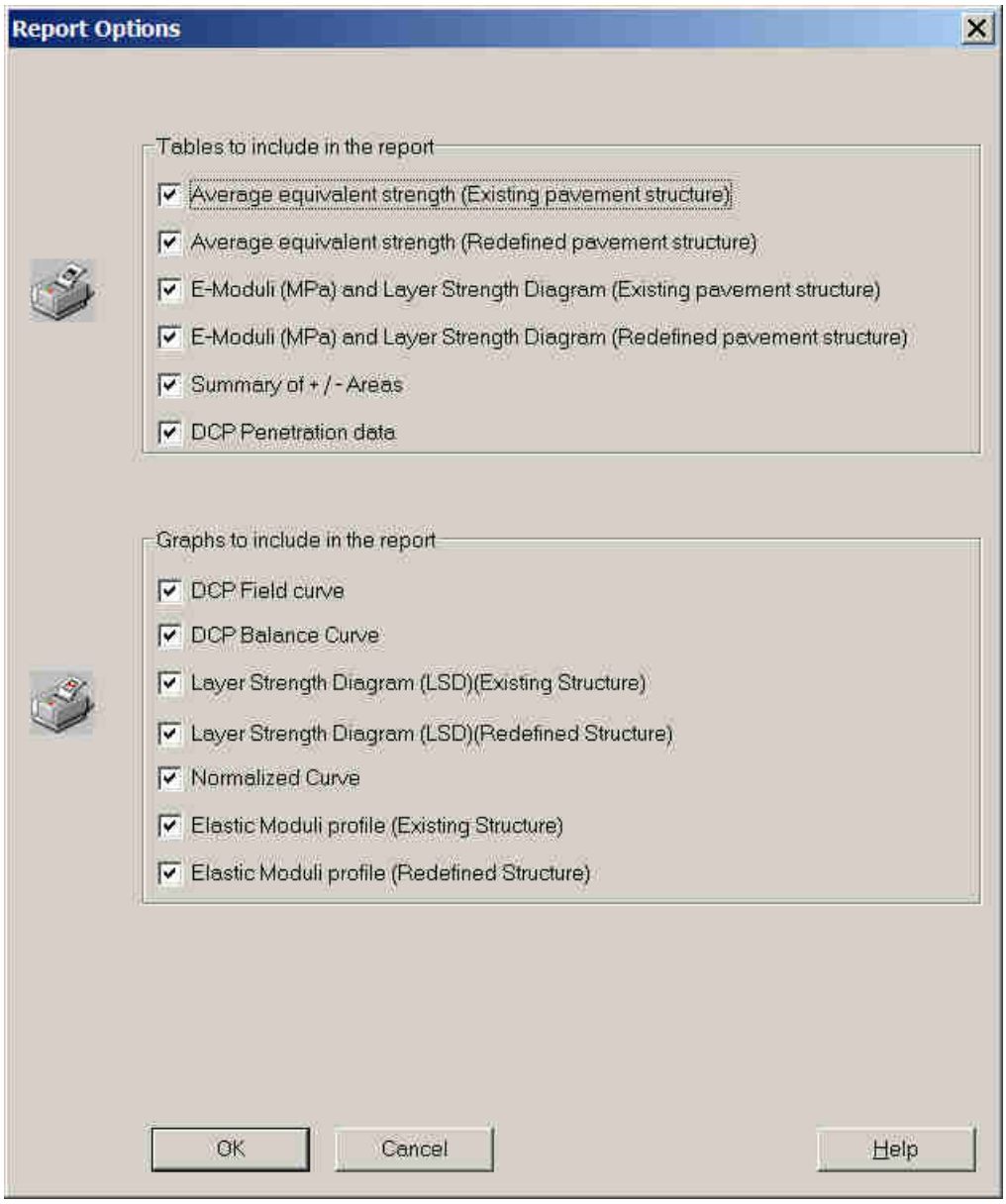


Figure 3. Default DCP Report options under system settings

5.2 Percentiles

Provision was made for several percentile combinations (P) values, i.e. 5P/95P, 10P/90P, 20P/80P, 50P/50P, 15P/85P, 25P/75P, 30P/70P, 35P/65P, 40P/60P, 45P/55P, that can be applied to the weighted DN values. (Note that weighted DN values of a homogenous layer are exactly the same as the arithmetic mean value).

5.3 Layer Strength Profiles

Layer boundaries are automatically determined and illustrated by default, depending on the DCP System settings. Layer strength profiles are illustrated by using layer default thicknesses, or by user defined thickness. In addition, automatic re-defined layer depths are available by re-defining it based on a published algorithm of data change detection (Zhao et al, 2013). A manual option for determination of layer boundaries is also included in the software. A standard data depth of 800 mm is used for DCP depth profiles.

5.4 Notes filed

A new option, tabbed "Notes" was included, for the purpose of capturing notes per DCP Test point, which the user may need to capture for further reference purposes.

6 Calculations

The "hart" of the software is to be found under the "Sections" menu. See Figure 4 below. It contains the following aspects:

1. Calculate all Properties (DSN_{450}, DSN_{800}, and DN) – for entire road under investigation;
2. DCP Test Points Data Validation – various panels for data validation;
3. Determine Sections from Properties, including DSN_{450}, DSN_{800}, and DN for all selected layers. Averages as well as cumulative sum of differences (CUSUM) values are plotted;
4. DCP Sections – default layer thickness of 150 mm added to pavement structure, if needed, based on evaluation for a specific TLC;
5. DCP Sections Report – graphical display of existing and new pavement layer configuration per defined DCP Section. This data to be exported to excel under "Save as Excel", if needed;
6. DCP Section Analysis per Section. Option to add user defined layers and thicknesses, depending on need per DCP Section defined in Item 4 above.

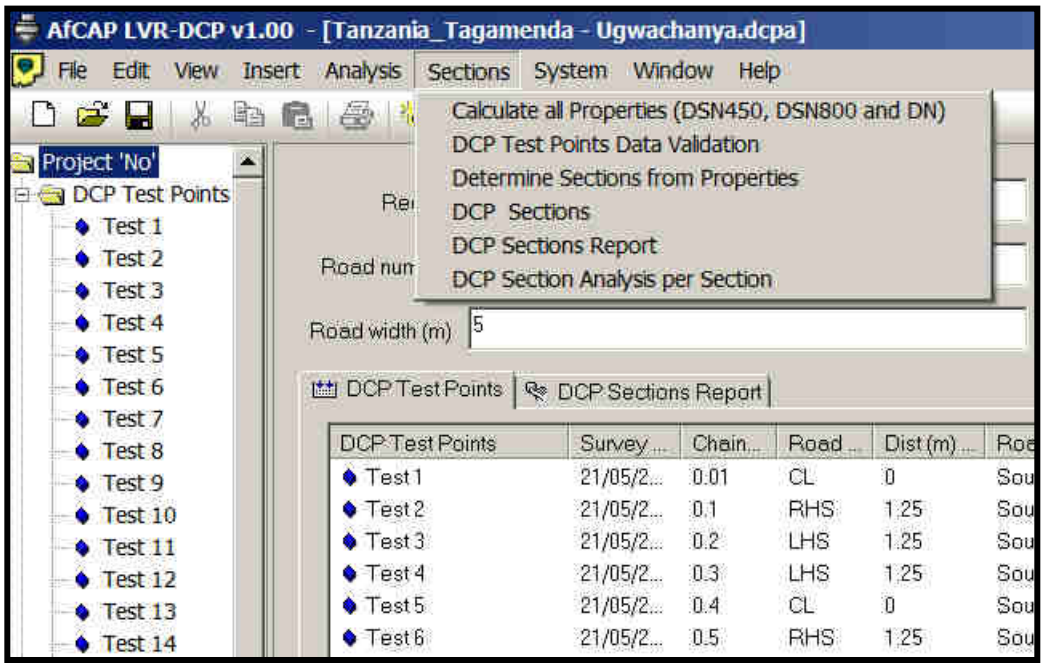


Figure 4. DCP Sections menu

7 Software Help File (SHF)

A Software Help File (SHF), integrated with hotlinks to the DCP software was also developed, and is only available from in the software, under title: “User Software Help File (SHF): AfCAP LVR-DCP v1.00”.

8 Conclusion

After many hours of workshops and development, it is concluded that a workable user friendly new standalone DCP design and analysis software package, named: “AfCAP LVR-DCP v1.00” was developed for use by AfCAP practitioners. The completion of the above activities according to the 21 items defined in Annex, brought the project to a successful conclusion. The final version of the AfCAP LVR-DCP v1.00 and associated SHF will be posted on the AFCAP website for use by registered practitioners, subject to conditions that may be set.

9 The Way Forward – Phase II

During the project time and the valuable deliberations the following items may need further development, i.e. “Phase II”.

9.1 Notes tab:

Although a new “Notes” tab was added to the current software (AfCAP LVR-DCP v1.00), it could be further improved with more functionalities and capabilities such as the ability to add or delete images. Text enhancements may also be added. Potential spell checker may be included into the “Notes” field.

9.2 Laboratory module:

The Peer Review Team (PRT) identified that a Laboratory DCP module should be designed and added to the current software. Although such a module was designed and built, more work need to be done before a final stage, acceptable to all will be reached. In addition, consensus needs to be reached on a new laboratory protocol for DCP testing need to be further developed and standardised.

9.3 User Design Manual for LVRs:

The need for an independent **DCP Design Manual for Low Volume Roads (LVRs)** was tabled during several of the workshop meetings. A draft manual was compiled and sent for comments. There is a need to further develop and finalise such a manual;

9.4 Feedback from Trainers

It is anticipated that some feedback on the use of the AfCAP LVR-DCP v1.00 software will be prepared by the PRT. This may result in further development work on the software.

10 References

M. I. Pinard, J. Hongve, P. Paige-Green, J.Rolt, K. Mukura and E. Mukandila. (2015). WinDCP Upgrade Stage 1 Workshop Report.pdf, AfCAP Project Reference Number RAF2049A, 7th December 2015.

M. I. Pinard, J. Hongve, P. Paige-Green, J.Rolt, K. Mukura and E. Mukandila. (2016a). WinDCP Upgrade Stage 2 Report Rev 1.pdf. AfCAP Project Reference Number RAF2049A, 8th January 2016.

M. I. Pinard, J. Hongve, P. Paige-Green, J.Rolt, K. Mukura and E. Mukandila. (2016b). WinDCP Upgrade Stage 3 Workshop Report.pdf AfCAP Project Reference Number RAF2049A, 20th January 2016.

Contract: GEN2023A-SC14007-CSIR-CONTRACT-27012015 v2.pdf. Contract Start date: 23rd January 2015.

Zhao, H., Lea, J., Harvey J. T., and Lea, J. (2013). Pavement structure segmentation method based on results derived from ground-penetrating radar data. International Journal of Pavement Engineering, 2013 Vol. 14, No. 4, 333–342, http://dx.doi.org/10.1080/10298436.2012.662594.

Annex: WinDCP Version 5-1-10002 modifications-improvements

Initial Work Description - User Requirements [or Terms of Reference (ToR)]:

Outcome of WinDCP Software Mini-Workshop
26th August 2013 (09.00 – 13.00), CSIR, Pretoria
Meeting Room: Khoroni Meeting Room B201, 2ND Floor, CSIR Built Environment
CSIR Facilitator: Dr Morris De Beer-Adapted after meeting dated October 20, 2014 Room C115, CSIR Pretoria (Item 21 added)

LAST NAME	*FIRST NAME*	*AFFILIATION/COUNTRY*	*OFFICE TEL*	*MOBILE*	*E-MAIL*
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Hongve	*Mr Jon*	*AFCAP*	*+47-48176177*		*joho@operamail.com*
De Beer	*Dr Morris*	*CSIR BE*	*012 841-2953*		*mbeer@csir.co.za*

The user requirements that follow here are based on the version of WinDCP Software indicated in 0 below:

Version detail of WinDCP5 on which the modifications/changes/additions are based is:

The Table below summarises the Items discussed during the mini-workshop on Aug 26, 2013, as well as during Train the Trainers meeting on Oct 20, 2014 at CSIR.

Table A1: Items and associated descriptions listed for Win DCP 5.1 modifications/improvements by CSIR

ITEM No:	ITEM	DESCRIPTION	CSIR COMMENTS/ACTIONS	OTHER COMMENTS
1	**Data entry screen:**	***Measurement no:*** *Defaults to zero when entering new measurement. Better default to 1. The number does not automatically increase by 1 when entering subsequent measurements. If you then forget to change the number manually and do say a Single Point analysis after having entered all the DCP values, the measurement number in the list to the left is locked with the result that you end up having two or more measurements in that list with the same number. In the Single/Average points analysis window the measurement number is however changed automatically.*	*Yes, Possible CSIR to change software accordingly. CSIR to adapt the xlsx template for DCP data entry as well.*	*Should start with Measurement 1*
2	**Existing road width:**	*No entry available for this. Good to record road width (in m) since it relates to the position of the measurement.*	*Yes, Possible/ CSIR to add accordingly.*	
3	**Position (from C/L):**	*Would it not be better to have the option to record the actual distance from Centre Line (C/L), then have a new drop down box for LHS/CL/RHS ? [Relative to CL e.g. 1.0 m LHS, or 1.5 m RHS].*	*Yes, Possible, but needs to be captured on field form. CSIR to add accordingly.*	

4	***Survey date:***	*Defaults to today's date. Should default to Project date of DCP measurements) so it doesn't have to be changed manually for every new measurement data entry for the same Project.*	*Yes, Possible/ CSIR to change software accordingly.*	
5	***Moisture conditions:***	*Indicate %-age range relative to OMC for each alternative. This will make it more self explanatory for new users.* *Change label to "Moisture condition of base" See "Republic of MALAWI Ministry of Transport and Public Works Design Manual for Low Manual Sealed Roads using the DCP design method June 2013". Also Drs Gerhard Jordaan/Paige-Green mentioned for percentages of OMC: Distinguish between Low Volume Roads (AFCAP) and High Volume Roads (SANRAL) DCP.*	*Suggest looking at "% moisture relative to OMC" as in Malawian DCP Design Manual and recent publications by Paige-Green (2011, 2012). It should, however, be remembered that OMC is a material characteristic – therefore only approximations can be coded for the "%-age range relative to OMC" of the wearing course and subgrade.*	

6	***DCP Design Curves (Layer Strength Design (LSD))***	*In the Design Curve Configuration window is an option to save the User Defined Design Curve with an alias (name). This alias does however not show up in the data entry screen**.*** *Further, why not have the predefined design curves from the DCP Design Catalogue – as standard options (using the proper names LE0.1, LE0.3 etc.) and do away with the Heavy, Medium and Light traffic options ?;*	*Need to discuss Design Curves further, as these were defined/* *Calibrated by former TPA experience (Mr E G Kleyn).* *How are the given LVR Design Curves calibrated?. Are they in accordance with the known BN_{100} = 40* *Balance requirement with minimum DSN800 = 80 ?. [A check revealed that the BN_{100} of given LVR Design Curves < 35, and DSN_{800} as low as 39].* *However, LVR Design Curves (LSD) can be coded into the software.*	

7	***Layer configuration:***	*The "DCP Catalogue" (actually LSDs) use standard layer thicknesses of 150 mm. However, it has been brought up by the Roads 2000 project in Kenya, that many upgrading projects will be done by labour based methods and that a base layer thickness of 100 mm sometimes would be more within the scope of these methods. Could we find a way to accommodate this?;*	*Currently, any positive layer thickness can be defined in the DCP Software. DCP Design should ideally be well balanced. This can be coded in to check.*	
8	***Data analysis:***	*The layer configuration in the Single/Average point analysis window is not automatically updated to the same as the layer thickness configuration in the DCP data entry screen. Should be corrected.*	*CSIR to change software accordingly.*	
9	***New Layer to be added:***	*Provide option for "New Layer" on top of existing pavement, if required from the initial analysis, and show the result in a "New pavement analysis" screen**.-***	*This is road Rehab/Upgrading Design – Coding can be done.*	
10	***Layers Strength Diagram (LSD) & Percentiles:***	*Provide more detailed Layer Strength Diagram:* *- Automatic calculation of both 20th, Mean (weighted average DN) and 80th %-ile, and exportable to xlsx.*	*This is road Rehab/Upgrading Design – Coding can be done.*	

11	***Structural Capacity (MISA):***	*Do away with the MISA Structural Capacity estimate if this is something we should not use anyway, or hide it somewhere; -*	*Why not use?. Software to provide for on/off toggle option.*	
12	***New xlsx Report Table:***	*An output table in a similar format to the one attached would be very useful. The %-iles would of course be in accordance with the selected road category. All the data are available from within the programme, it's just a matter of programming the output report. Otherwise it is extremely tedious to manually transfer all this data manually from the Single Point Analysis screen into an Excel Spreadsheet.*	*Create export option for "Output Table" to Excel. CSIR to add option accordingly.*	
13	***CUSUMs:***	*The designer then has all the data readily available for the final analysis, can delete whatever is irrelevant (e.g. 20th or 80th %-ile) and can do the Cusum analysis quite easily by inserting new columns and formulas*	*CUSUMs to be defined better & and for which DCP parameter. DSN_{800}, DN, etc. CSIR to*	

Road no / Name - Summary and analysis of DCP test results

				0-150 mm			151-300 mm			301-450 mm			451-600 mm			601-800 mm		
Measurement	Chainage	Position	DNS800	20% %-ile	Mean	80th %-ile	20% %-ile	Mean	80th %-ile	20% %-ile	Mean	80th %-ile	20% %-ile	Mean	80th %-ile	20% %-ile	Mean	80th
1	0+000	CL																
2	0+100	1.5 m RHS																
3	0+200	1.5 m LHS																
4	0+300	CL																
5	0+400	1.5 m RHS																
6	0+520	CL																
DCP Catalogue specification			≥73		≤4			≤9			≤19			≤25			≤39	

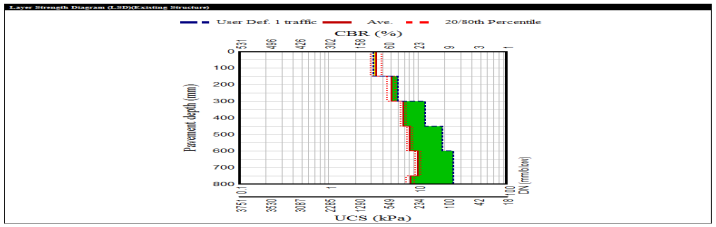
			change software accordingly. *Study UK DCP3.1 for alternative option for layer identification – via straight line option: "Manual layer analysis". Include DN for straight line selected.*	
14	***User manual & Help Files:***	*Badly needs updating to be of any use to new users. Maybe Interactive for training purposes. Urgent need for "Train the Trainers"*	*OK, Possible – but will be time consuming. Manual/Help file to be synchronised with the software.* *Suggest providing for a worked example of existing pavement DCP analysis as well as road upgrading/rehabilitation.* *Add short section on UKDCP3.1.*	

15	***Use of arithmetic mean or weighted mean:***	*In the older versions of the DCP programme, the arithmetic mean was used to calculate DN values. In the latest version, the weighted mean is used. Have the various Layer Strength Diagrams (LSD) and other related printouts been amended accordingly?.*	*Yes, weighted average used throughout software. However, the user to be aware that for a uniform layer, arithmetic average and weighted average converged to the same value.*	
16	***Zero point for penetration readings:***	*TMH6 requires that the DCP cone be knocked into the top of the pavement layer until the shoulder is flush with the surfacing – not the top of the base layer. In contrast, it appears TPA practice (Ed Kleyn) does not follow TMH 6 procedure and knocks in DCP cone to be flush with top of base course. These different procedures can make a significant difference to the DN values obtained. Need to clarify procedure**.***	*Not a software issue – this is a test protocol issue?. Suggest sticking with TMH 6, but removal of thin seal layers can be done, however, users to be alert to very thin weak interlayers between thin surfacing and top of base. – See Netterberg and De Beer (2012) and De Beer et al (2012) SAICE references.*	

17	***Programme to be used for pavements with granular and cemented layers:***	*The DCP programmes for granular or lightly cemented BASE LAYERS are different, depending on whether they are applied to granular or lightly cemented BASE layers. What happens when the base is granular and the subbase is cemented? Which programme should be used?*	*Base layer type determines which method of estimate of Structural Capacity is used. [Granular different from Cemented].*	

18 | ***Alternative (Table) printout (xlsx) for Layer Strength Diagram (LSD):***

For training purposes, it is easier to illustrate the pavement layer deficiencies in an alternative format as illustrated below. Any possibility of programming this alternative printout



- *A comparison of the in situ and required layer-strength profiles can also be presented manually for each uniform section to facilitate the determination of upgrading requirements as illustrated in Table A-2.*

Table A-2: Comparison of in situ and required layer strength profiles for uniform sections

Pavement Layer (mm)	Required DN Value for LV 0.3 ??- Need to adhere to Pavement Balance Concept.	DN Values - 80th Percentile* Section no. – Different DCP data file sets						
		1	2	3	4	5	6	7
0-150	≤ 3.2	8.07	4.81	4.90	4.03	4.45	6.57	3.95
150-300	≤ 6	10.47	7.75	10.07	5.37	5.99	9.71	4.94
300-450	≤ 12	9.69	8.78	10.27	7.79	7.09	9.68	7.37

Inadequate in situ layer
Adequate in situ layer(s)

A.14 Step 12 – Determine Upgrading Requirements

- *As illustrated in Table A-2, the in situ strength of the uppermost 150 mm layer of the existing unpaved road (DN range 3.95 – 8.07 mm/blow) is all below the required strength (max. DN value of 3.2 mm/blow). Thus, at least a new base layer of the required strength*

This is for Road Upgrading/Rehab. Suggestion to add "AFCAP-DCP ROAD UPGRADE" Module in the current software. This can be coded in software as new tab option.

Suggest adding an option to shift LSD data graphically up and downing, or portioning sideways relative to Design Curve for new layer, or layer improvement.

Tables to be exportable to xlsx as well as text copy & paste.

[See Item 14 as well].

will be required.

- *As illustrated in Table A-3, the effect of adding a new base layer is to subjugate the existing base layer to that of a subbase layer with a lower strength requirement which must be evaluated against the required DN value of ≤ 6.*

Table A-3: Impact of imported base layer on layer-strength profiles

Pavement Layer (mm)	Required DN value for LV 0.3	DN Values - 80th Percentile						
		Section no.						
		1	2	3	4	5	6	7
0-150	≤ 3.2	3.20	3.20	3.20	3.20	3.20	3.20	3.20
150-300	≤ 6	8.07	4.81	4.90	4.03	4.45	6.57	3.95
300-450	≤ 12	10.47	7.75	10.07	5.37	5.99	9.71	4.94
450-600	≤ 19	9.69	8.78	10.27	7.79	7.09	9.68	7.37

Required new base with DN value ≤ 3.2
Inadequate in situ layer(s)
Adequate in situ layer(s)

- *As illustrated in Table A-3, the strength of the new subbase (previously the base of the existing gravel road) in two if the uniform sections, Sections 1 and 6, is inadequate (DN value > 6). Thus, a new subbase layer of the requisite strength is also required for these sections to produce an adequate pavement structure for all sections as illustrated in Table A-4.*

Table A-4: Impact of imported base and subbase layers on layer-strength profiles

Pavement Layer (mm)	Required DN value for LV 0.3	DN Values - 80th Percentile						
		Section no.						
		1	2	3	4	5	6	
0-150	≤ 3.2	3.20	3.20	3.20	3.20	3.20	3.20	
150-300	≤ 6	6.00	4.81	4.90	4.03	4.45	6.00	
300-450	≤ 12	8.07	7.75	10.07	5.37	5.99	6.57	
450-600	≤ 19	10.47	8.78	10.27	7.79	7.09	9.71	

Required new base with DN value ≤ 3.2
Required new subbase with DN value ≤ 6.00
Adequate in situ layer(s)

19	***Software Versions, Licences and costs:***	***Other Issues:*** *1) Inform users when new versions (updates) of WinDCP program is available.* *2) License codes,* *3) cost of software and development.*	*CSIR to advice/recommend on these.*	
20	***Variable number of blows:***	*Investigate if there is a need to allow number of blows (and or penetration depth) to be variable.*	*Study this option, also check UK DCP3.1.*	
21	***Laboratory DN-Determination Module***	*Add a module for entering & display Laboratory DCP data & DN value, with associated graphics.*	*Added on Monday Oct 20, 2014.*	
	References:	*De Beer, M., Maina J.W. and Netterberg F (2012). Weak Interlayers in Flexible And Semi-Flexible Road Pavements – Part II. Journal of the South African Institution of Civil Engineering, Vol 54 No 1, April 2012, Pages 43–54, Paper 762-2.* *Kleyn E.G. and Steyn W.J. vdM (2011). Pavement Strength Balance and Its Practical Implications. 10th Conference on Asphalt Pavements for Southern Africa, CAPSA 2011.* *Kleyn, E.G. and Steyn W.J.vdM. (2010). Utilizing Traffic Molding of Pavements Towards More Cost Efficient Pavement Design and Management. Proceedings of the 2nd International Conference on Transport Infrastructures. Sao Paulo, Brazil.* *Malawi Manual (2013); Design Manual for Low Volume Sealed Roads Using the DCP Design Method. Ministry of Transport and Public Works, REPUBLIC OF MALAWI, June 2013.*		

		Netterberg F and De Beer, M., (2012). Weak Interlayers in Flexible And Semi-Flexible Road Pavements – Part I. Journal of the South African Institution of Civil Engineering, Vol. 54 No 1, April 2012, Pages 32–42, Paper 762-1. *Paige-Green, P and Pinard, M.I. (2012). Optimum Design Of Sustainable Sealed Low Volume Roads Using The Dynamic Cone Penetrometer (DCP). 25th ARRB Conference – Shaping the future: Linking policy, research and outcomes, Perth, Australia 2012, © ARRB Group Ltd.* *Paige-Green, P. (2011), Applying the Dynamic Cone Penetrometer (DCP) design method to low volume roads, Proc 15th Africa Regional Conference on Soil Mechanics and Geotechnical Engineering, (ARC), Maputo, 2011, pp 422-430.* *UK DCP 3.1 User Manual: Piouslin Samuel and Simon Done (2006). Measuring Road Pavement Strength and Designing Low Volume Sealed Roads using the Dynamic Cone Penetrometer. Unpublished Project Report UPR/IE/76/06 Project Record No R7783, UK Department for International Development (DFID).*		

End of Annex.

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