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Evaluation of Cost-Effectiveness and Value-for-Money of DCP-DN Pavement Design Method for Low-Volume Roads in Comparison with Conventional Designs

Final Report

Authors: M I Pinard, G van Zyl and J Hongve

ReCAP Project Reference Number. RAF 2128A

March 2019

Infra Africa Consultants
Gaborone, Botswana

Cover Photo: Authors

Quality assurance and review table			
Inception Report	Author(s)	Reviewer(s)	Date
Version 1	M I Pinard and G van Zyl	N Leta	9th January 2018
		L Sampson	16th January 2018
Version 2	M I Pinard and G van Zyl		23 January 2018
Preliminary Evaluation Report			
Version 1	M I Pinard, G van Zyl and J Hongve		31st March, 2018
		N Leta	26 April 2018
		L Sampson	29 April 2018
Draft Final Evaluation Report	M I Pinard, G van Zyl and J Hongve		17 May 2018
Final Evaluation Report	M I Pinard, G van Zyl and J Hongve		24 July, 2018
		N Leta	25 July, 2018
			25 July, 2018
Final Evaluation Report	M I Pinard, G van Zyl and J Hongve		14 December, 2018
		N Leta	03 January, 2019
		J Cook	03 January, 2019
Final Evaluation Report Ver 4	M I Pinard, G van Zyl and J Hongve		21 January, 2019
Final Evaluation Report Ver 5	M I Pinard, G van Zyl and J Hongve		05 March, 2019
		N Leta	06 March, 2019

ReCAP Project Management Unit
Cardno Emerging Market (UK) Ltd
Oxford House, Oxford Road
Thame
OX9 2AH
United Kingdom

Key words

Low-volume roads, pavement design, Dynamic Cone Penetrometer, cost-benefit analysis, life-cycle cost.

RESEARCH FOR COMMUNITY ACCESS PARTNERSHIP (ReCAP)

Safe and sustainable transport for rural communities

ReCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa and Asia. ReCAP comprises the Africa Community Access Partnership (AfCAP) and the Asia Community Access Partnership (AsCAP). These partnerships support knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. The ReCAP programme is managed by Cardno Emerging Markets (UK) Ltd.

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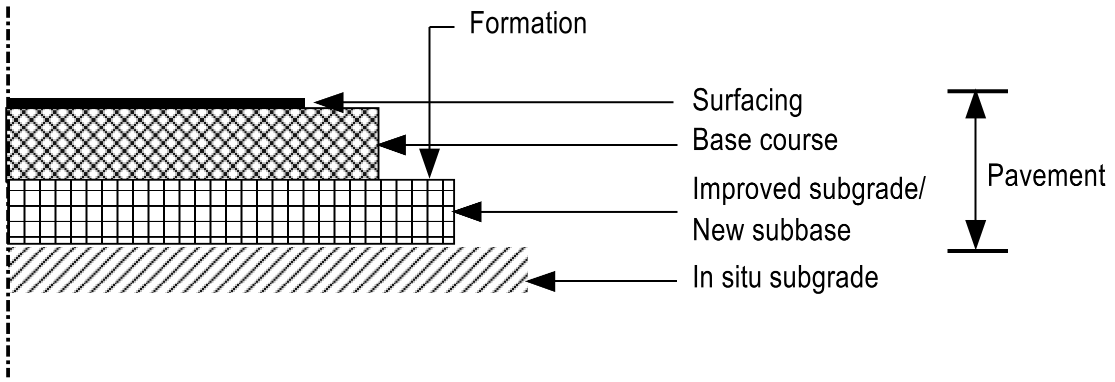
Acronyms, Units and Currencies

AASHTO	American Association of State and Highway Transport Officials
AfCAP	Africa Community Access Partnership
CBA	Cost-Benefit Analysis
CBR	California Bearing Ratio
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
DN	The average penetration rate in mm/blow of the DCP in a pavement layer
EMC	Equilibrium Moisture Content
EOD	Environmentally Optimised Design
LCC	Life-cycle costs
MESA	Million Equivalent Standard Axles
OMC	Optimum Moisture Content
PMU	Project Management Unit
ReCAP	Research for Community Access Partnership
SEACAP	South East Asia Community Access Programme
TLC	Traffic Loading Class
ToR	Terms of Reference
TPA	Transvaal Provincial Administration
TRL	Transport Research Laboratory
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)
VFM	Value for Money

Terminology



Components of a low volume sealed road

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Executive summary

ReCAP has supported the enhancement of a method of pavement design for low volume roads (LVRs) based on the use of the Dynamic Cone Penetrometer (DCP) (AfCAP, 2013) as an alternative to the more traditional methods based on the use of the California Bearing Ratio (CBR). Despite the perceived advantages of this relatively new method of design, they are yet to be fully quantified in practice. This has prompted the letting of a project pertaining to the "Evaluation of cost-effectiveness and value-for-money of the DCP-DN pavement design method for low-volume roads in comparison with traditional designs".

The main purpose of the project is to evaluate, in terms of cost-effectiveness (upfront cost savings and life-cycle costs) and value-for-money, a number of unpaved road sections located in selected African countries that were upgraded to a paved standard using the DCP-DN method. This has entailed the collection and analysis of road cost data for these road sections in order to determine their life-cycle costs in comparison with the same section of unpaved[1] (gravel) road upgraded to a paved standard using traditional, CBR-based pavement design methods for low volume roads (TRH4, DCP-CBR and ORN31). Additional objectives are to evaluate the outcome (uptake) and potential impact of the DCP-DN method.

As part of the evaluation procedure, 36 "in-situ" designs were undertaken based on actual design information from 10 road sections located in countries in west, east and southern Africa. These in-situ designs were supplemented by a relatively large number of "hypothetical" designs, some 2304 in all, which were based on a wide range of road environmental conditions likely to be encountered in practice (3 traffic classes, 4 in-situ subgrade conditions, 2 climatic zones, 6 material types and 3 haul distances). Thus, it is practicable only to present the global cost trends for the various design methods that were evaluated in terms of the following:

- pavement cost and pavement cost ratios (DCP-DN versus other design methods).
- total project cost and project cost ratios (DCP-DN versus other design methods).
- total project cost savings/km (DCP-DN versus other design methods).

In view of the fact that the roads are all relatively new and without a performance history that would allow end of design life roughness values, and hence VOCs to be determined, as well as maintenance cost interventions and residual values, the cost comparison boiled down just to pavement construction costs.

In keeping with the above approach, the key findings of the analyses emanating from the hypothetical designs, which have been found to be reflective of the outcome of the in-situ designs, are presented in Section 3 and may be summarized as follows:

(1) At design traffic loading up to about 0.7 MESA, and for a wide range of subgrade strengths and climatic zones, the DCP-DN design method will, in the majority of cases, provide pavement construction cost savings in the range of USD 10,000 -20,000 per km, and in many cases in excess of USD20,000/km when compared against all other methods. These costs savings are reduced by about 30 to 60% for the zero-haulage scenario.

(2) The pavement construction cost savings offered by the DCP-DN method occur to a lesser extent in the higher Traffic Loading Classes (TLCs) (0.7 MESA and above) when, in some cases, other design methods, particularly ORN31, are more cost-effective in this higher traffic range.

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[1] The terms *paved* and *unpaved* are referred to in some countries as *sealed/surfaced* and *unsealed/ unsurfaced* roads respectively. These terms mean essentially the same thing, i.e. an unpaved/ unsealed/ unsurfaced road is one without a permanent waterproof surface and may consist of locally available earth/sand or imported gravel material. In contrast, a paved/sealed/surfaced road is one in which the surface has been permanently paved/sealed/surfaced by the use of a wide range of surfacing types made from bitumen, concrete, clay bricks, etc. The terms paved and unpaved are used in this report.

In general terms, the difference in pavement construction costs per km for the various design methods, and the pavement construction cost efficiency of the DCP-DN design method, relative to the other design methods, decreases with higher quality subgrades and higher TLCs. Also, for the specific set of environmental conditions considered, there is no major difference in the trends between Wet and Dry-Moderate environments.

The conclusion to be drawn from the very wide range of design evaluations is that, in general, the DCP-DN method is the most cost-effective design option at relatively low TLCs, up to about 0.7 MESA and across all subgrade strengths. However, at TLCs above 0.7 MESA the method gradually becomes less cost effective than the other methods, particularly ORN31, which become more cost-effective in many situations.

The pavement costs derived for the hypothetical and in-situ designs mirrored each other closely, and the resulting trends for pavement construction cost as well as total project construction cost differences/km, were similar. However, it should be noted that there would be potentially larger project construction cost differences in countries with higher material costs compared to those in South Africa.

It is also interesting to note that ORN31 has been shown to be generally more cost-effective than its successor for LVR design, the DCP-CBR method, in all design environments. This may be partly explained by two reasons:

(1) ORN31, together with the DCP-DN method, and in contrast to the DCP-CBR and TRH4 design methods, allows for the use of unsoaked subgrades which offer scope for using relatively thinner/less costly pavement structures.

(2) The adopted soaked/unsoaked subgrade CBR ratio for the DCP-CBR method appears to be very conservative compared to that adopted in the DCP-DN and ORN31 methods. This results in the need for relatively thicker/more costly, pavement layers.

One of the major benefits of the hypothetical evaluation spreadsheets is that they can be used by practitioners to determine the likely costs of their designs in a particular set of road environment conditions, and which is the most appropriate design method to use. The spreadsheets also offer the potential for being developed as an application tool for undertaking LVR design based on a set of input parameters.

Based on a visual condition survey of four of the DCP-designed roads that have been in service from 6 – 28 years, and are located in both dry-moderate and wet climatic zones, they are all rated to be in fair-good condition. However, lack of future maintenance could jeopardise their long-term performance.

In terms of Value for Money (VFM), the DCP-DN method has been evaluated in terms of the following:

(1) ***Cost-effectiveness:*** The outcome of the various cost evaluations undertaken and summarised above illustrate the general cost-effectiveness of the DCP-DN method in the lower traffic ranges up to about 0.7 MESA against the other design methods.

Given that many countries in Africa have embarked on programmes for improving basic access in rural areas by upgrading gravel roads to a paved standard, typically of the order of 100 – 150 km/annum, the potential benefits of adopting the DCP-DN method over a 5-year planning horizon, could result in cost savings of the order of USD60 – 180 million, depending on the extent of the upgrading programme and the road environment conditions. When extrapolated to all 46 Sub-Saharan countries, this figure is estimated at USD 2.7 – 18 billion. Such an upgrading policy would also conserve large quantities of higher quality material for future use as the need for stronger pavements increases.

(2) ***Outcome (uptake) and knowledge*:** This has been assessed in terms of the following:

a. *Sustainability*: This has been demonstrated in terms of the following typical examples:

   i. Seminars, workshops and meetings aimed at knowledge sharing between participating ReCAP countries and their wider community of practitioners.

   ii. Establishment of Working Groups or Steering Committees with the objective of discussing intensively issues associated with the environmentally optimised design of LVRs.

   iii. Construction and long-term monitoring of demonstration or trial sections designed on the basis of the DCP-DN method.

   iv. Contributions in kind from partner Governments in terms of staff time and funding/co-funding with bi-lateral partners.

   v. The holding of basic and advanced training courses in the DCP-DN method of design for engineers and technicians in a number of African and Asian countries that have led to the certification of four AfCAP Level 1 Trainers which qualifies them to undertake such training nationally or internationally.

(b) *Uptake:* This has been manifested as follows:

   i. ReCAP country partner financing of the DCP-DN design method in three countries so far.

   ii. Incorporation of the DCP-DN design method requirements in local standards and specifications in at least four countries so far, and on-going revisions in at least another five countries.

(c) *Quality of DCP-DN research:* This has been manifested as follows:

   I. Production of at least one internationally peer-reviewed paper on the DCP-DN method of design in the research proceedings of a major civil engineering institution in the UK

   II. Production and presentation of at least 7 papers on the DCP-DN method of design in a number of regional and international conferences.

(d) *Knowledge of the DCP-DN method.* This has been manifested as follows:

   i. An increase in the knowledge base for the DCP-DN method of pavement design which is gradually increasing in terms of the following:

      - The number of certified trainers who have themselves applied the method in practice in at least three countries.
      - Incorporation in at least one international course in Rural Roads for Development held at the University of Birmingham, UK.

(3) ***Potential impact:*** Although it may be too soon to start quantifying the impact of introducing the DCP-DN method of design for the more recently constructed trial sections, or of adopting any DCP-related method of design for future LVRs, such impacts are likely to be a factor within the causal package leading to:

a. Reduced cost/increased cost-effectiveness of LVR provision.

b. Optimum use of non-renewable gravel resources.

c. Improved transport services at cheaper costs.

d. Increase in agricultural production and productivity due to more reliable, all-season access to market places.

e. Improvements in education and health due to communities being able to access such facilities in all seasons.

f. Increased resilience to climate impacts due to more durable paved road surfaces.

g. Ultimately, poverty reduction in the vicinity of the project due to improvements in community livelihoods.

In summary, the use of the DCP-DN method and, indeed other methods such as ORN31 when applied to relatively high design traffic loadings (>0.7 MESA) in some road environments, is expected to provide Value for Money in terms of the following:

a. Cost-effectiveness.
b. Outcome (uptake) and knowledge.
c. Potential impact.

In terms of the way forward, and based on the many lessons learnt during the course of undertaking this project, the following recommendations are made:

(1) A practitioner's workshop should be held to discuss and disseminate the findings of this report.

(2) As part of the on-going ReCAP project on Long Term Pavement Performance (LTPP) monitoring of trial sections in a number of partner countries, measurement of in-situ moisture in the pavement layers and subgrade, and across the horizontal profile of the sections, should be given high priority in order to validate the assumptions made on this parameter in all the design methods.

(3) In order to embed in practice the potential benefits to be derived from the use of the DCP-DN method, a generic guideline on the Design of Low Volume Roads should be produced so as to provide practitioners with another choice of design method for their consideration.

(4) The Regional Research Centres should undertake a similar data collection exercise to the one initiated under this project, in say 5 years time, so as to consolidate on the preliminary results of the VFM exercise initiated under this project.

(5) Consideration should be given to developing the spreadsheets prepared under this project as an application tool for undertaking LVR design based on any set of input parameters to determine what are the likely costs of their designs in a particular set of road environment conditions, and which is the most appropriate design method to use.

(6) Consider the following topics for further research to enhance the efficacy and applicability of the DCP-DN design method

    a. Determine the precision limits of the DCP-DN measurement as against the CBR measurement as adopted by other LVR design methods.

    b. Compare the designs produced by the DCP-DN and other design approaches (DCP-CBR, TRH4 and ORN31) with an analytical approach.

    c. Use suitably calibrated road investment appraisal models such as HDM-4 or the World Bank's Roads Economic Development Model (RED) to appraise robustly the LCCs of the DCP-DN and other design approaches.

1 Introduction

1.1 Background

One of the key goals of the DFID-supported Research for Community Access Partnership (ReCAP) is to promote safe and sustainable rural access in Africa and Asia through research and knowledge sharing between participating countries and the wider community. In this regard, the Programme focuses on conducting high quality, applied research that will assist Low Income Countries (LICs) to increase all-weather rural access to poor communities. It builds on the strengths of AfCAP and SEACAP in working alongside partner Governments to encourage high levels of research uptake.

The expected outcome of the Programme is “Sustained increase in the evidence base for more cost effective and reliable low volume rural road and transport services, promoted and influencing policy and practice in Africa and Asia”. A key aspect of the attainment of this outcome is the cost-effective provision of low volume roads (LVRs) based on the use of appropriate pavement design methods. To this end, ReCAP has supported the enhancement of a method of pavement design based on the use of the Dynamic Cone Penetrometer (DCP) as an alternative to the more traditional California Bearing Ratio (CBR)-based design methods. Both methods are based on measurement of a proxy for the in-situ shear strength of a material. In the case of the DCP-DN method, it is the resistance to penetration of a material by a DCP cone - the DN value (mm/blow) whilst, in the case of the DCP-CBR method, it is the ratio of the force per unit area per minute required to penetrate a soil mass, to the force required for a similar penetration of a standard crushed rock material – the CBR value (%).

1.2 Motivation for Project

For a variety of perceived advantages, there is, in a number of countries in Africa and Asia, an increasing uptake of the DCP-DN method of design, as against the more traditional CBR-based approaches to the design of LVR pavements (Rolt and Pinard, 2016). The main advantages of the DCP-DN method and, indeed, all other DCP-related methods of design, are that it:

- Involves the use of relatively low cost, robust apparatus that is quick and simple to use (approx. 30 minutes per test). This allows many measurements of pavement layer thicknesses and strengths to be obtained to provide a comprehensive characterization of the in-situ road conditions. This provides a strong statistical basis for design, minimizing the risks of under- or over-design inherent in any method that does not provide sufficient information for a proper statistical analysis.
- Provides improved precision limits compared to the CBR test (Smith and Pratt, 1983). The strength (DN) values obtained in the field or the laboratory are inherently more accurate because the DCP provides a virtually continuous strength profile throughout the layer being tested (+/- 150 mm) whereas a CBR test is naturally biased towards the ends of the test mould at a penetration depth of 2.5 or 5.0 mm. Moreover, it has been shown that with reasonable care taken to control testing errors, DCP data can be treated as representative of in-situ materials characteristics (Roy, 2007).
- Involves testing actual subgrade strength using the DCP at multiple points along the road at the time of the year when subgrades are weakest as well as under multiple seasonal scenarios in contrast to CBR-testing which is relatively costly and time consuming to carry out, requiring a large amount of material for laboratory testing at relatively large spacing – typically every 500 to 1000 metres. Moreover, the entire subgrade to a depth of 800 mm is assessed in-situ by the DCP in 150 mm layers, as opposed to the more traditional approach in which composite samples are typically taken from the top 300 – 500 mm of the subgrade for CBR testing to determine a

representative subgrade design CBR to define uniform sections. However, when the materials differ significantly in the top 500 mm (a common occurrence), the design CBR from a composite sample can be misleading.

- Provides a standalone means of improving the quality control of compacted materials from density-based methods, which tend to be slow, potentially hazardous (nuclear gauges) and of uncertain accuracy, particularly where there is a variation in site materials along any tested section (Livneh and Livneh, 2013; Hongve and Pinard, 2016) to stiffness/strength-based methods which allows direct comparison to be made between design and achieved strengths on site (Siekmeier et al, 2009).
- Offers a holistic approach to the provision of LVRs in that the DCP test can be used for field investigations, pavement design, laboratory testing and compaction quality and layer thickness control.

In the case of the DCP-DN method only:

- Avoids the need to convert the DCP-DN values to equivalent CBR values at any stage of the design process which would incur errors due to the relatively poor correlation between DCP and CBR measurements with material specific correlation coefficients ranging from 0.67 – 0.79 (Sampson and Netterberg, 1990).

The main limitations of using the DCP device, in conjunction with any DCP-related method of design, include the following (Rolt and Pinard, 2016):

- If the existing pavement contains material that is very coarse the DCP probe may ‘hit’ a large stone or be deflected sideways creating friction on the shaft resulting in incorrect readings. This may require some DCP tests to be abandoned or repeated.
- If the pavement contains a cemented layer the DCP may not be able to penetrate. To obtain information about the underlying structure a suitable sized hole may have to be drilled through the cemented layer without using water for lubrication. Similarly, if carried out on an existing road, the drilled hole will need to be made good in such a manner as to not affect the integrity of the road and lead to future water ingress.
- The DCP tests may be performed poorly (e.g. hammer not falling the full distance, non-vertical DCP, excessive movement of the depth measuring rod, use of a blunt cone, etc.). Any test can be poorly executed and therefore this is not a particular limitation of the DCP test. However, the DCP test is less operator susceptible than many other tests thus reducing the risk of measurement error (Livneh and Ishai, 1987).

In addition to the above, the DCO approach is empirically founded with the associated caveats of extrapolating empirical procedures to other environments.

Despite the perceived advantages of the DCP-DN method of pavement design, they are yet to be fully quantified. This has prompted the letting of a ReCAP project pertaining to the *“Evaluation of cost-effectiveness and value-for-money of DCP-DN pavement design method for low-volume roads in comparison with traditional designs*”.

1.3 Purpose and Scope

The main purpose of the project is to evaluate, in terms of cost-effectiveness and value-for-money, a number of unpaved road sections located in selected African countries that were upgraded to a paved standard using the DCP-DN method. This has entailed the collection and analysis of the construction costs of these road sections in order to determine their life-cycle costs in comparison with the same sections of roads upgraded to a paved standard using traditional, CBR-based pavement designs. In addition, the project has also evaluated the outcome (uptake) of the DCP-DN method and knowledge as well as its potential impact.

As indicated in the Terms of Reference (ToR), the scope of work associated with the attainment of the above objectives was as follows:

1. **Stage 1:** Undertaking of a desk study of the design, construction and maintenance activities that have been carried out on each road section. This was based on design reports, completion reports (as-built information), monitoring reports, where available, as well as other sources.
2. **Stage 2:** Visiting some of the roads in each country to get an appreciation of their in-service performance and current condition.
3. **Stage 3**: Holding meetings with relevant authorities in-country to familiarise them with the objectives of the study.
4. **Stage 4:** Compiling information on construction costs, maintenance costs and computing life-cycle costs for each road section.
5. **Stage 5:** Preparing an evaluation report providing a comparison of the pavement costs, total project costs and project cost difference per km of the three typical, traditional design methods against the DCP-DN design method as well as the cost-effectiveness and value-for-money aspects of the EOD approach incorporating the DCP-DN design method.

Following completion of Stage 1 of the project – a desk study of alternative methods of pavement design for LVRs - which was reported upon in the Inception Report, the subsequent stages of the project have included the following:

(1) Field visits and data collection in the various countries involved in the project with the objective of compiling information on construction and maintenance costs as well as undertaking a qualitative assessment of the performance of these roads

(2) Determination of the pavement structures derived from application of four design methods (DCP-DN, DCP-CBR, ORN31 and TRH4) based on actual input data pertaining to the design traffic loading, in-situ subgrade strength and climatic environment pertaining to the ten road sections located in the various countries.

(3) Determination of the pavement structures derived from application of the four design methods based on a “hypothetical” approach involving a relatively wide range of input factors in terms of traffic loading, in-situ subgrade strength and climatic environment.

(4) Application of the construction cost data to the various pavement structures as a basis for determining the LCC for each design method (both in-situ and hypothetical) and, subsequently the pavement cost ratios, total project cost ratios and total project cost difference per km for the four design methods evaluated.

(5) Preparation of an Evaluation Report including the outcome of the LCC analyses and the determination of Value-for-Money aspects of the DCP-DN design method.

1.4 Final Evaluation Report

This Final Evaluation Report is structured as follows:

An Executive Summary that summarises the main findings of the report.

Section 1 (this section): A brief introduction to the project including its purpose and scope.
Section 2: The approach and methodology for undertaking the life-cycle cost analyses.
Section 3: The LCC evaluation procedure and key outcomes.
Section 4: The evaluation of value-for-money pertaining to the use of the DCP-DN design method.
Section 5: A summary of key findings and conclusions of the project.

2 Approach and Methodology

2.1 General

The ToR required the Consultant to focus on 10 road sections in 5 countries, namely: Malawi, Zambia, Ghana, Tanzania and Kenya. However, since the design traffic loading on these roads is all relatively low (up to 0.3 MESA), the range was extended by inclusion of two road sections from South Africa, one of which has carried an estimated 0.8 – 1.0 MESA).

Based on the above, the number of design scenarios for a particular road section is relatively limited in that it would have produced only 36 designs (4 design methods x 1 traffic class x 1 subgrade strength x 1 climatic zone x 3 material types x 3 borrow pit haulage distances) from which to draw conclusions relating to the cost-effectiveness of the DCP-DN against the other CBR-based methods. This number of "in-situ" designs was considered to be too few to draw definitive conclusions on the cost-effectiveness of the various design methods that, in practice, could be applied to a much larger number of design scenarios. As a result, a "hypothetical" approach also had to be considered as described below.

2.2 Hypothetical Approach

In view of the above, it became necessary to also include a "hypothetical" approach for evaluating the cost-effectiveness of the various design methods. This approach allows a much larger number of design scenarios to be considered in a wide range of road environments, some 2304 in all (4 design methods x 3 traffic classes x 4 subgrade strengths x 2 climatic zones x 6 material types x 4 borrow pit haulage distances[2]). The design matrix for the hypothetical approach is discussed further in Section 4.

2.3 Selection and Requirement of Design Methods

2.3.1 Selection of design methods

The criteria that were used to select the LVR design methods for comparison with the DCP-DN method are as follows:

- Developed specifically for LVRs
- Developed for generic rather than country-specific application
- Widely used in the African region

Based on the above criteria, the design methods that were selected for comparison with the DCP-DN method are as follows:

- ORN31
- TRH4
- DCP-CBR (TRL)

2.3.2 Applicability of DCP Methods of Design

DCP-based methods of design, such as the DCP-DN, DCP-CBR and ORN31 design methods, if appropriately applied in line with their stipulated design catalogues and procedures, can be applied to most design situations found in practice in tropical and sub-tropical regions of the world. It should be noted, however, that the DCP method cannot be used directly if the proposed road is in cut or on fill, where the final formation level of the alignment would be outside the influence zone of an existing alignment DCP survey. In such cases, the material to be used for the embankment would need to be tested to determine its properties at varying densities and moisture contents. Fills can then be

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[2] Three haulage scenarios were originally considered in the hypothetical approach for evaluating the cost-effectiveness of the various design methods – low: 1 - 10 km, medium: 10 – 30 km and high: 30 – 100 km. However, a request was made for consideration to be also given to a zero-haulage scenario. The implications of this are discussed on page 37.

designed in accordance with the relevant catalogue to ensure that all the layers comply with the specifications of the respective design method. This will allow designers to go straight to design catalogues for contractual quantities.

In areas of significant widening, the approach would be as described above, depending on whether the widening would involve a cut or fill situation.

2.3.3 Input requirements

As with all empirical methods of pavement design, the four main requirements of the design procedure are generally as follows (Rolt and Pinard, 2016):

- Assessment of subgrade strength.
- Assessment of design traffic loading.
- Selection of pavement materials.
- Determination of pavement layer requirements (thickness and/or strength).

Apart from the determination of traffic loading, which is generally quite straight forward, the other aspects of the design procedure all vary quite significantly between the methods under consideration and, as a result, must be fully understood in order to produce credible designs. For this reason, a brief description of the key features of the four design methods is provided below:

2.3.4 DCP-DN method

The DCP-DN design method is empirical in nature and the findings are currently based on measurements and observations on a range of soil types and environmental conditions prevailing in South Africa. The method is now being commonly and effectively used in a number of countries in Africa, including Malawi, Tanzania, Ghana and Kenya and could be effectively used in geotechnical environments similar to those countries. In dissimilar environments, further verification and performance monitoring may be required. Details of the development and application of this design method have been summarised in the Inception Report and are documented in other literature (e.g. Kleyn, 1984; Paige-Green and Van Zyl, 2018).

Assessment of subgrade strength: This is based on the strength (DN value) of the subgrade layer at the anticipated long-term equilibrium moisture content (EMC) of the road after it has been upgraded or rehabilitated to a paved standard. Depending on environmental conditions, the EMC in the subgrade may be expected to equilibrate above, at or below OMC when compacted to the highest practicable field density, i.e. refusal density or “compaction to refusal” which is a specific feature of the DCP-DN method.

Selection of pavement materials: This is based on the following procedure:

(a) The evaluation of earthworks, subgrade and pavement materials on the basis of their characterisation as defined by relevant materials testing in terms of grading, plasticity, deleterious inclusions (e.g. organics) or other specific properties such as swell, erodibility or collapse potential.

(b) The selection of materials in terms of acceptability for specific use is then based on judgment related to a combination of specified criteria allied to engineering judgment, bearing in mind the preference for local material use on LVRRs.

(c) Once acceptability is agreed, the use of DCP-DN procedures to select and control the use of materials that have been previously defined as acceptable.

Testing to ascertain the durability properties of the material is undertaken separately from the DCP-DN test based on appropriate durability testing.

Determination of pavement layer requirements: This is specified in a single DCP-DN structural catalogue **(Annex A)** that prescribes the pavement layer thicknesses and strengths in 150 mm increments to a depth of 800 mm, i.e. the required strength profile. The layer strengths are varied in relation to traffic loading and increase (decreasing DN value) gradually in relation to an increase in design traffic loading. The design method can be adapted for any selected layer thicknesses or materials available. The catalogue is based on the DCP assessment and performance of more than a thousand road sections carried out in the 1970s (Kleyn and van Zyl, 1989) and subsequent investigations (Paige-Green, 1994).

2.3.5 DCP-CBR method

Details of the development and application of this design method have been summarised in the Inception Report and documented in other literature (e.g. Gourley and Greening, 1999).

Assessment of subgrade strength: This is based on the in-situ worst-case long term conditions similar to that obtained in the laboratory soaked CBR test. However, in a dry/moderate climate it is assumed that the subgrade CBR strength value is halved which is equivalent to a shift upwards of one subgrade class (Gourley, 2002). The DN values are converted to CBR values, based on the TRL (as distinct from the Kleyn) DCP-CBR correlation, for input into a CBR catalogue. It should be noted, however, that the ratio between soaked and unsoaked CBRs is significantly less than the research-based ratios developed by both Emery (Emery, 1985) and Paige-Green (Paige-Green et al, 1999). This is likely to lead to the use of higher quality/thicker/more costly pavement layers.

Selection of pavement materials. This is based on the laboratory soaked CBR test, regardless of climate, and at a specified density likely to be attained in the field. Requirements are placed on the allowable plasticity and grading of the material, the limits of which are related to the class of material, i.e. the higher the class, the more stringent the limits and the type of material, i.e. different for pedogenic and non-pedogenic materials.

Determination of pavement requirements (thickness and/or strength): This is based on the use of two structural design catalogues, one for dry-moderate climates (N-value > 4) and one for wet climates (N-value < 4). **(Annex B).** Pavement layer thicknesses are variable and range from 120 mm to 275 mm. For a given traffic loading, layer strengths and/or thicknesses are higher/greater in the wet zone than in the dry/moderate zone.

2.3.6 TRH4 method

Details of the development and application of this design method have been summarised in the Inception Report and documented in other literature (e.g. COLTO, 1996).

Assessment of subgrade strength: This is based on the soaked CBR value, regardless of climatic zone. A minimum CBR value of 3% at 95% Mod. AASHTO is assumed for design purposes, but lower layers in the catalogue may be omitted if the subgrade CBR strength is higher than 3% or, conversely, added if the subgrade CBR strength is lower than 3%

Selection of pavement materials. This is based on the soaked CBR value. In addition, requirements are placed on the allowable plasticity and grading of the material, the limits of which are related to the class of the material, i.e. the higher the class, the more stringent the limits as stipulated in TRH4 (CSRA, 1985).

Determination of pavement requirements (thickness and/or strength: This is based on the use of two structural design catalogues, one for dry-moderate climates (N-value > 2) and one for wet climates (N-value <2) **(Annex C).** Pavement layer thickness varies between 100 and 200 mm and layer strengths are varied in relation to the geo-climatic zones – dry/moderate (Weinert N value > 2) and wet (Weinert N value < 2). Thus, for a given traffic loading, layer strengths are higher in the wet zone than in the dry/moderate zone.

2.3.7 ORN31 method

Details of the development and application of this design method have been summarised in the Inception Report and documented in other literature (TRL, 1993).

Assessment of subgrade strength: This is based on the moisture content equal to the wettest moisture condition likely to occur in the subgrade after the road is opened to traffic, i.e. the long-term, in-service, equilibrium moisture content. Three categories of subgrade condition are assessed:

(1) **Category 1 Subgrade** where the water table is sufficiently close to the ground surface to control the subgrade moisture content. In this case, the moisture content is determined from similar roads in the vicinity or from a knowledge of the relationship between suction and moisture content for the subgrade soil. In practice, this moisture content is likely to be at or above OMC.

(2) **Category 2 Subgrade** with deep water tables and where rainfall is sufficient (> 250mm) to produce significant changes in moisture conditions under the road. The moisture condition for design purposes can be taken as the optimum moisture content given by the BS Standard (Light) Compaction Test (2.5 kg rammer method).

(3) **Category 3 Subgrade** in areas with no permanent water table and where the climate is dry throughout most of the year (annual rainfall 250 mm or less). For design purposes a value of 0.80 OMC obtained in the BS Standard (light) Compaction test (2.5 kg rammer method).

Selection of pavement materials. This is based on the soaked CBR of 80% for the basecourse and 30% for the subbase, regardless of climatic zone. Requirements are placed on the allowable plasticity and grading of the pavement materials, the limits of which are related to the design traffic class and moisture regime, i.e. the higher the class and the wetter the anticipated moisture regime, the more stringent the limits.

Determination of pavement requirements (thickness and/or strength): This is based on the use of one structural design catalogue (**Annex D).** Pavement layer thickness varies between 100 and 350 mm and layer strengths are varied as discussed above. The layer strengths are varied in relation to traffic loading and increase (decreasing DN value) gradually in relation to an increase in design traffic loading.

2.4 Design Assumptions

A number of key assumptions underlie the application of all four design methods discussed above, as follows:

2.4.1 Drainage

Drainage is undoubtedly one of the most important factors that affects the long-term performance of a LVR, given adequate construction practice, maintenance attention and control of overloading. Thus, the assumed long-term equilibrium moisture content (EMC) is critical in that it affects the strength of the material in the pavement layers and the subgrade.

For purposes of the pavement design and LCC analyses, it has been assumed that, for all four design methods under consideration, **adequate drainage prevails.** In terms of currently recommended practice, this means that the level difference between the crown of the road and the invert of the drain (gradient dependent), should be about 0.75 m on relatively flat ground and slightly less on steeper ground) and, where feasible, the level distance between the original ground level and the underside of the subbase layer should be about 0.15 m. If these requirements are achieved in practice, then from research findings (Emery,1985) it can be expected with a high degree of probability that:

- The EMC in the subgrade equilibrates below OMC in dry climates (annual rainfall < 500 mm) or at, or below, OMC in wet climates (annual rainfall > 500mm) **(Annex E).**
- The EMC in the pavement layers is independent of climate with the average moisture content equilibrating below OMC (0.63 OMC in the base and 0.78 in the subbase **(Annex E).**

For the in-situ designs, the implications of the above findings are that where adequate drainage prevails, and where the entire width of the road is sealed to the front slope of the side drain (a design requirement) then pavement layers and the subgrade are assumed to operate in an unsoaked condition, i.e. at or below OMC, irrespective of climatic zone. However, for the DCP-DN design method, it has been assumed, conservatively, that the in-situ moisture content will be equivalent to OMC.

Soaked designs for the pavement and subgrade could, of course, be warranted, due to poor drainage, high water tables, occurrence of flood plains, etc., but these scenarios would require special design considerations which, in any case, would be over-ridden by the assumptions adopted for the road designs, as indicated above, and do not feature in the pavement structures subjected to LCC analyses for the in-situ or hypothetical designs.

2.4.2 Maintenance and overload control

For purposes of the LCC analysis, it is assumed that adequate maintenance and overload control prevail and apply equally to all four design methods under consideration. As regards the former factor, the required periodic maintenance interventions and their timing are assumed to be broadly similar for a well-constructed, appropriate surfacing type placed on pavement structures of similar bearing capacity. However, as indicated in Section 3.2.3-Life Cycle cost analysis, in the absence of a performance history of the road sections, the LCC analysis has boiled down to a comparison of initial construction costs only.

2.4.3 Terrain

It is assumed that the in-situ designs for the 10 road sections apply to situations where the road is located in either flat or rolling terrain (max. gradient < 8%), and not for steep or very steep gradients where structural surfacings would be required, such as concrete slabs (reinforced/unreinforced), concrete blocks, etc. may be required. In these situations, design methods, other than those being considered in this project, would be required and are outside the scope of this project.

2.4.4 Materials compliance

Although not always necessarily the case, it is assumed for the purposes of the LCC analyses that the materials located from the borrow pits are compliant with the requirements of the particular design method. In practice, this may not be the case and the material may either be rejected or possibly mechanically modified at some additional costs to meet simultaneously the specification requirements in terms of strength (CBR), grading and plasticity.

2.4.5 Representative DN Values

In practice, many methods rely on the use of the DCP to determine uniform sections of the road under design by undertaking a CUSUM analysis of the range of values within that uniform section as follows:

(a) **DCP-DN:** Uses the 80th, 50th or 20th percentile of the range of values depending on whether the anticipated long-term EMC in the pavement is respectively wetter than, the same or drier than at the time of the DCP survey.

(b) **TRH4:** Uses the 90th/10th percentile of the range of CBR/DN values found along the road, as determined from a DCP survey.

(c) **DCP-CBR:** Uses the mean, lower quartile or lower decile value of the range of CBR/DN values as in Table 1 below (Gourley and Greening, 1999):

Table 1: Dependence of design subgrade values on design traffic class (DCP-CBR method)

Design traffic class	Design CBR/DN
< 0.3 MESA	Mean CBR
0.3 – 0.5 MESA	75th/25th percentile
0.5 – 1.0 MESA	90th/10th percentile

(d) **ORN31:** Use the 90th/10th percentile of the range of CBR/DN values within a uniform section as determined from a DCP survey.

The above percentile values for the different design methods were used in the determination of the design subgrade strength in a uniform section of road for pavement design purposes.

2.4.6 Conversion from DN to CBR

The following relationships were used to convert DN values to CBR values as developed by Kleyn (Kleyn, 1984) and TRL (Samuel and Done, 2005).

(1) Kleyn: $CBR = 410 \times DN^{1.27}$
(2) TRL: DN = 10^ (2.48 – Log CBR)/1.057

It should be appreciated however, that the conversion from DCP-DN values to equivalent CBR values at any stage of the design process will introduce errors due to the relatively poor correlation between DCP and CBR measurements (material specific correlation coefficients range from 0.67 – 0.79; Sampson and Netterberg, 1990).

2.4.7 Conversion from in-situ DCP CBR to laboratory soaked CBR values

A key requirement for comparing the pavement structures derived from the various pavement design methods is to convert the in-situ DCP-CBR values to equivalent laboratory soaked CBR values for use in the DCP-CBR, TRH4 and ORN31 methods. This was achieved by using the relationship between soaked CBR values and field DCP-CBR values as developed by Paige-Green et al (1999) from their LVR database (see Table 2).

Table 2: Relationship between in-situ DCP CBR and soaked CBR (Paige-Green et al, 1999)

Relationship between DCP CBR and G class for unsealed roads							
Material classification	Soaked CBR	Approximate field DCP-CBR: Unsealed road					
		Subgrade		Wearing Coarse			
		Wet	Dry	Very dry	Dry	Moderate	Damp
G4 or NG80	80	-	-	260	205	151	96
G5 or NG45	45	-	-	188	148	109	69
G6 or NG25	25	56	66	146	115	85	54
G7 or G/S15	15	52	62	137	108	79	50
G8 or G/S10	10	39	46	101	80	59	37
G9 or G/S7	7	38	44	-	-	-	-
G10 or G/S3	3	35	41	-	-	-	-

Note: Very dry = 0.25 OMC, Dry = 0.5 OMC, Moderate = 0.75 OMC and Damp = OMC

By way of example, a wearing course material with a DCP CBR value of 54 at OMC would be equivalent to a soaked CBR value of 25.

2.5 Field Visits and Data Collection

2.5.1 General

Field visits were made to the countries listed in Table 3, except for Kenya, for the purpose of obtaining information on construction and maintenance costs as well as for undertaking a qualitative assessment of the performance of some of these roads. The cost information for Kenya was not suitable as the construction included widening of the road which could not be disaggregated from the pavement construction costs.

Table 3: Road sections to be evaluated

Country	Road Name	Length (km)	Date of constr.	Type of Surfacing
Ghana	Akyem Kukurantumi – Asafo (Eastern Region)	1	Not yet started	-
Malawi	Kasinje-Kandau (Ntcheu District)	8.5	2016	Cape Seal
	Mwanza-Kunenekude (Mwanza District)	8	2016	Cape Seal
	Parachute Batallion-Lifuwu (Salima District)	8	2016	Cape Seal
	Linthipe-TC-Lobi	5	Not yet started	-
Kenya	D379-Wamwangi-Karatu	0.45	2012	CMA
Tanzania	Lawate- Kibongote (Siha District)	14	2012	DSD
S. Africa	Danger Point road 4019 (Western Cape)	6.5	2003	SSD + SS
	Nelshoogte road (R38 – Nelshoogte Sawmill)	6.5	1991	DSD
Zambia	T2 – Waitwika – D1 (Nakonde District)	1	Not yet started	-

During the country visits meetings were held with the AfCAP national coordinator and road agency personnel in order to inform them to the objectives of the project. Visits were also made to some of the road sections in Malawi, Tanzania and South Africa where the roads had already been constructed, and discussions held with the local communities to try and obtain some idea of the impact of these paved roads on their livelihoods.

2.5.2 Construction costs

The unit construction cost information required for applying to the different pavement structures determined from both the in-situ and hypothetical designs included the following:

- Cost of material, stockpiled at borrow pits and crushers, ready for loading.
- Load plus free haul of 1km.
- Haul costs per four range distances, including a zero-haulage scenario.
- In-situ rip and recompact costs.
- Plant and labour costs to construct different layer thicknesses..

The format for collecting the cost information from the various countries is presented in Table 4 below which includes typical costs obtained from South African contractors, converted to US dollars (USD/ZAR = 12).

Table 4: Material unit costs

Layer Quality	Material Unit Costs (USD/m^3)							
	Crusher-Bin Commercial	**Borrow pit – Bin natural**	**Plant and Labour Costs by Layer Thickness**					
			100 mm	**120 mm**	**125 mm**	**150 mm**	**175 mm**	**200 mm**
NG3		1.67	6.92	5.98	5.50	4.58	3.85	3.16
NG7		1.67	6.92	5.98	5.50	4.58	3.85	3.16
NG10		1.67	7.37	6.22	5.88	4.50	4.00	3.28
NG15	12.92	1.67	8.13	6.95	6.50	5.42	4.50	3.75
NG25	12.92	1.67	8.13	6.95	6.50	5.42	4.50	3.75
NG30	12.92	1.67	8.13	6.95	6.50	5.42	4.50	3.75
NG45	14.63	1.67	9.38	8.02	7.50	6.25	5.17	4.23
NG55	16.99	1.79	9.91	8.48	7.93	6.61	5.46	4.47
NG65	19.36	1.90	10.45	8.94	8.36	6.96	5.76	4.71
NG80	22.92	2.08	11.25	9.63	9.00	7.50	6.20	5.08
Crushed>100	29.58	2.08	12.50	10.70	10.00	8.33	6.89	5.64

Note: NG3 = Natural gravel with a soaked CBR of 3.

Borrow pit haulage costs, independent of material type, were also obtained from South African contractors as presented in Table 5 below.

Table 5: Material haulage costs

In situ rip & recompact (USD/m^3)		3.75
Load & 1 km (USD/m^3)		2.08
Haul costs (USD/m^3km)	**1 - 10 km**	0.42
	10 - 30 km	0.33
	30 - 100 km	0.29

In the event, the required construction cost information in the format required was available only from Zambia, Tanzania and South Africa. In Ghana, Malawi and Kenya the Bill of Quantities is priced in a manner that does not differentiate the haulage material cost by quality or by hauling distance. As a result, it became necessary to use the South African costs for input in the LCC analyses for Ghana, Malawi and Kenya. Since the South African haulage costs are competitively driven, and the type of plant and equipment used for road construction in most countries is very similar, the outcome of the cost comparison evaluations is expected to be realistic.

2.5.3 Maintenance costs

From discussions with stakeholders in Malawi, Tanzania and Kenya, it appears that no systematic maintenance has been carried out on any of the LVRs since they were constructed, in some cases (Tanzania) more than 5 years ago. However, as discussed in Section 3.2, such costs are assumed to be broadly similar.

2.5.4 Performance of Trial Sections

During the field visits, a visual condition survey was undertaken to determine the condition/ performance of those sections of DCP-DN designed roads that had been in service for at least 6 years. These included:

(1) Kenya: D379-Wamwangi-Karatu road: Design life = 15 years; 6 years in service; no maintenance carried out since construction.

(2) Tanzania: Lawate- Kibongote road: Design life = 15 years; 6 years in service, no maintenance carried out since construction.

(3) South Africa: Danger Point road 4019 (Western Cape): Design life = x years; 15 years in service; intermittent routine and periodic maintenance carried out.

(4) South Africa: Nelshoogte road (R38 – Nelshoogte Sawmill): Design life = x years; 27 years in service; intermittent routine and periodic maintenance carried out.

The outline details of the above roads, and the outcome of the visual condition survey that was undertaken during the field visits are summarized **Annex F**. From the outcome of the visual assessments, it was observed that:

(1) The four DCP-DN designed roads mentioned above have all performed satisfactorily in relation to their design parameters.

(2) No maintenance has been carried out on any of the roads, except for the two in South Africa. Continued lack of adequate maintenance poses a potential threat to their longer-term performance.

3 LCC Evaluation Procedure

3.1 General

A fair, equitable and transparent approach to undertaking the evaluation of cost-effectiveness of the DCP-DN method of pavement design for LVRs in comparison with traditional design methods is essential, if the outputs are to be credible. To this end, this section presents the following:

- The method of life-cycle cost analysis considered appropriate for use on the project.
- The principles that will be applied for determining the cost-effectiveness of the various LVR design methods under consideration.

3.2 Comparative Cost Evaluation

3.2.1 General approach

The approach envisaged in the ToR for undertaking a comparative cost evaluation of the alternative methods of pavement design for upgrading from an unpaved (gravel) road standard to a paved standard is as follows:

1) Determine construction costs as well as life-cycle costs (LCC) of upgrading from an unpaved (gravel) road to a paved road based on:

   (a) the use of the DCP-DN method, and

   (b) the use of selected, traditional CBR-based design methods.

2) Compare the LCC derived from (a) and (b).

3.2.2 Life-cycle cost components

In general, a LCC analysis includes consideration of all costs anticipated over the life (or analysis period) of the road. The principal components of such an analysis typically includes the following:

- agency costs
- initial construction and rehabilitation costs
- maintenance costs over the design period
- benefits due to savings in user costs over the analysis period
- salvage costs.

In order to convert all the costs and benefits that may occur throughout the life of each road option, a discounted cash flow technique may be used to determine the Net Present Value (NPV) of each option on which basis the preferred option can be determined from the following relationship:

$$NPV = C + \sum M_i (1 + r)^{-X}{}_{i} - S(1 + r)^{-Z}$$

Where: NPV = present worth of costs
C = present cost of initial construction
M_i = cost of the i^{th} maintenance and/or rehabilitation measure
r = real discount rate
X_i = number of years from the present to the i^{th} maintenance and/or rehabilitation measure within the analysis period
Z = analysis period
S = salvage value of the pavement at the end of the analysis period expressed in terms of present values

Agency costs

Agency costs include those costs incurred by the agency in undertaking the planning, design and administration aspects of implementing a road project. They have been excluded from the LCC analysis as they are assumed to be broadly similar for all the design options.

Construction and rehabilitation costs

For a given road with a specific design traffic loading that is located in a particular road environment (terrain, subgrade conditions, moisture and temperature regimes, etc.), the unit cost of construction will depend primarily on the type of pavement structure required by the particular design method in terms of quality/thickness of the pavement layers. It is assumed that, over the design life of the LVRs under consideration, major rehabilitation would not be required.

Maintenance costs

The maintenance required on a LVR is a function of the rate and nature of road deterioration which will be dependent on pavement composition, traffic loading and environmental influences. An assessment needs to be made of future annual routine maintenance requirements, periodic treatments, such as reseals, and rehabilitation such as structural overlay.

Road user costs

Road user costs are those costs incurred by road users travelling on the road and are typically an aggregation of three separate components: Vehicle Operating Costs (VOC), which are influenced by the roughness of the road, Traffic Accident Costs and User Delay Costs.

Salvage costs

The salvage value of the pavement at the end of the analysis period depends on the extent to which it can be utilized in any future upgrading. For example, where the predicted condition of the pavement at the end of the analysis period is such tat the base layer could serve as the subbase layer for the subsequent project, then the salvage value would be equal to the cost in current value terms for construction in future to subbase level discounted to the evaluation year.

3.2.3 Life-cycle cost analysis

The ToR require an evaluation to be carried out of the cost-effectiveness of the DCP-DN pavement design method with a view to assess the benefits/cost savings accruing to Road Authorities, in terms of both the upfront cost savings and life-cycle costs, as a result of adopting the method in comparison with the more traditional, CBR-based design methods. Whereas the former requirement is possible due to the availability of reliable construction costs data, the latter requirement would only be possible if all the 10 roads/trial sections being evaluated were:

- founded on a similar strength subgrade
- located in the same road environment with replication of the trials in a variety of road environments.
- properly constructed and adequately maintained over their design life
- monitored at least at the end of their design life in terms of the total traffic carried since construction (in MESAs), roughness cracking, rutting, etc. so as to be able to determine relative benefits due to savings in user costs over the analysis period and their relative salvage values.

In fact, most of the road sections being evaluated are either not yet constructed or, those that have, are less than 6 years old. Thus, there is no performance history of these road sections that can be used in a typical LCC analysis as described above. As a result, the cost evaluation boils down essentially to a comparison of initial construction costs rather than overall life-cycle costs with the former being related to the type of pavement structure (layer strength/quality and thickness) dictated by the design method adopted.

3.2.4 Hypothetical life-cycle cost evaluation

Notwithstanding the above, it should be noted that the structural capacities (based on DSN_{800}) of the pavement structures produced by the four design methods are broadly similar with the structural capacity of the DCP-DN method being very similar to all of the other design catalogues up to about 0.1 MESA, after which it becomes slightly more conservative (Paige-Green and van Zyl, 2018). This being the case, it would seem not unreasonable to assume that:

- the pavement structures would be expected to deteriorate in a broadly similar manner under a given traffic loading and road environment.
- the cost of the periodic maintenance interventions for the roads/trial sections would be broadly similar and, when discounted to the base year, would be relatively small in comparison with the construction costs (the non-traffic related routine maintenance costs are assumed to be the same for all the roads/trial sections).
- the roughness generated by a relatively small number of commercial vehicles on the roads/trial sections, and hence the related VOCs, would be broadly similar and, when discounted to the base year, the difference in VOC savings would be relatively small in comparison with the construction costs. Most roughness variations on new LVRs are built-in during construction and are not traffic related.

Based on the above assumptions, the outcome of the cost comparison, based on initial construction cost, would seem likely to be reflected in the outcome of a more traditional LCC analysis based on actual performance history data, had such data been available for inclusion in the analysis.

3.2.5 Cost-effectiveness of design methods

The principle that was applied in determining the cost-effectiveness of the various LVR design methods discussed in Section 3.3 is simply to determine the construction cost per design method per design scenario and then the construction cost ratios between the DCP-DN and alternative CBR-based design methods. In this regard, in the hypothetical designs, the same unit costs of construction for the DCP-DN designed roads will be applied to the traditional design methods. This will allow the pavement and project costs for the DCP-DN method and the other design methods to be derived as illustrated in Figure 1.

In the case of the in-situ designs, country specific construction costs, where available, have been used.

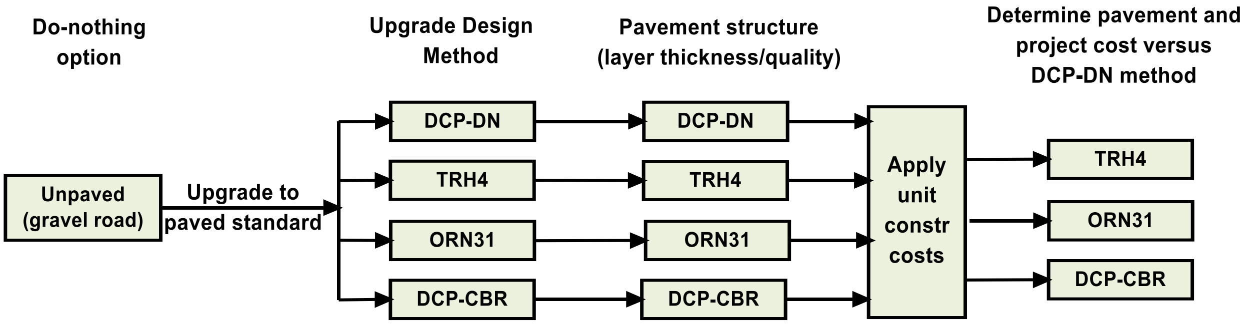


Figure 1 : Procedure for determining cost-effectiveness of various LVR design methods

3.3 Hypothetical Designs

3.3.1 General

The flow chart for undertaking the hypothetical cost evaluation of the pavement structures derived from the various design methods is illustrated in Figure 2.

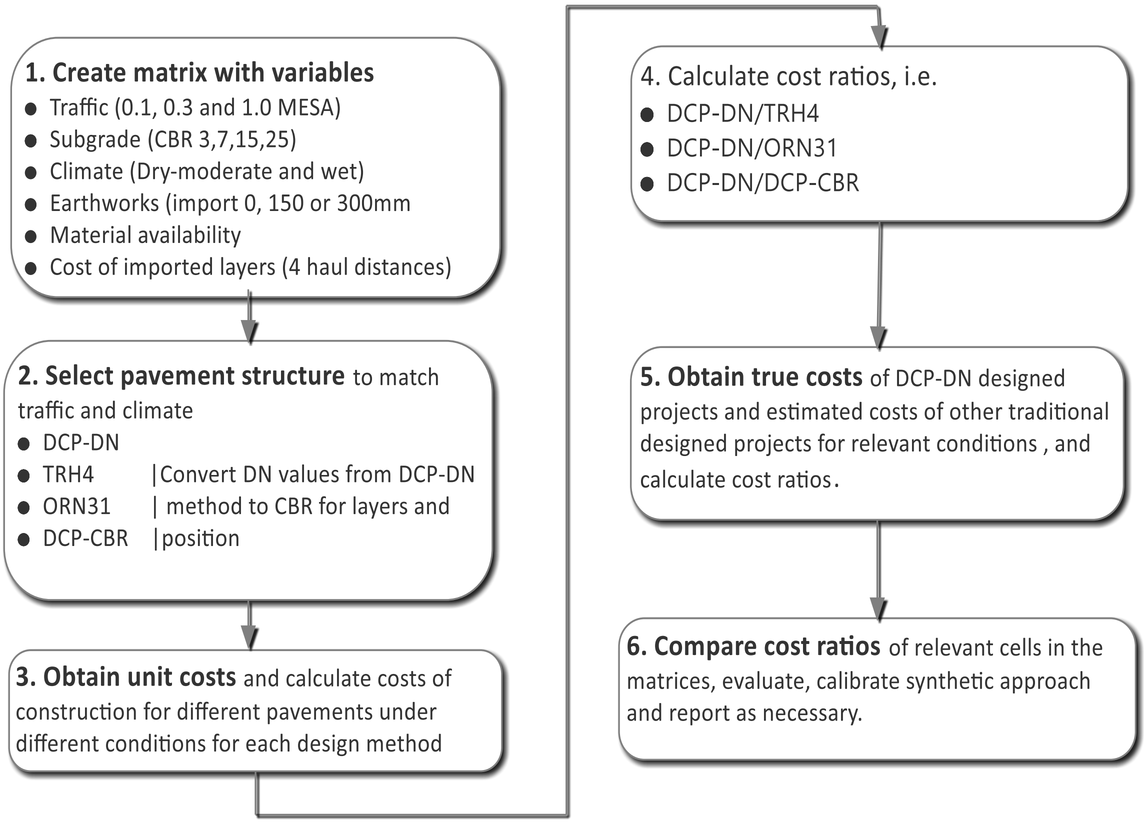


Figure 2: LCC evaluation procedure

3.3.2 Design matrix

The design matrix variables for the hypothetical evaluation incorporates the following variables:

- **Traffic (MESA)**
  - Low: < 0.1
  - Medium: 0.1 – 0.3
  - High: 0.3 – 1.0
- **In-situ subgrade** (quality of the existing gravel road upper layers (300 mm) in three quality ranges defined as follows):
  - Very Good: CBR 25/30
  - Good: Soaked CBR = 16 - 24
  - Fair: Soaked CBR = 8 - 15
  - Poor: Soaked CBR = 3 - 7
- **Climatic zone**
  - Dry – moderate: TRH4: N > 2; DCP-CBR: N > 4)
  - Wet: TRH4: N < 2; DCP-CBR: N < 4
- **Material Quality** (as specified in the structural catalogues of the different design methods).
  - CBR 15, CBR 25, CBR 25/30, CBR 45, CBR 55, CBR 65, CBR 80.

- **Borrow pit haulage**
  - Zero haulage
  - 1 – 10 km
  - 10 – 30 km
  - 30 – 100 km

Based on the above design variables, a design and pavement structure cost matrix was developed as presented schematically in Table 6. It allows for 18 possible different pavement structures for each of the 4 design methods, thereby covering most scenarios likely to be encountered in practice.

Table 6: Example of design and pavement structure cost matrix

Traffic				**Low (< 0.1 MESA)**							
Subgrade				Very Good (NG25)		Good (NG15)		Fair (NG7)		Poor (NG3)	
Moisture regime/ climate				Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero								
			Low								
			Medium								
			High								
	NG25/30	Cost of layer/s import	Zero								
			Low								
			Medium								
			High								
	NG45	Cost of layer/s import	Zero								
			Low								
			Medium								
			High								
	NG55	Cost of layer/s import	Zero								
			Low								
			Medium								
			Zero								
			High								
	NG65	Cost of layer/s import	Zero								
			Low								
			Medium								
			High								
	NG80	Cost of layer/s import	Zero								
			Low								
			Medium								
			High								

3.3.3 Determination of typical pavement structures

The determination of a typical pavement structure based on the various design methods may be illustrated for the TRH4 design method with the following input data:

Design details:
Design traffic loading = 0.3 MESA
Existing subgrade/layer quality on which to construct (Soaked CBR=3)
Wet climatic environment
Available material close to site (free haul distance) = Natural Gravel (NG) with soaked CBR = 15

TRH4 Catalogue
The TRH4 catalogue for a wet environment and 0.3 MESA indicates the pavement structure as shown in Table 7. A standard convention has been adopted in the hypothetical evaluation spreadsheet for describing each pavement layer and is used for comparison purposes between the different design methods.

Table 7: TRH4 Class D pavement structure for 0.3 MESA

TRH4 (Wet)		
Road Category	**MESA**	**Synthetic evaluation**
	0.1 - 0.3	
D	S	S
	100 G4	B(100-80)
	125 G6	SB(125-25)
	150 G9	S(150-7)

The convention in Table 7 is as follows:
First character (B=Base, SB=Subbase,
S= Selected)
Following three characters after bracket define the layer thickness (100mm, 120mm, 125mm, 150mm, 175mm or 200mm)
Following two characters define the required soaked CBR of the layer material

The quality of the in-situ subgrade and the distance required for import of layers are evaluated and information captured as explained below (refer to cell shaded in blue in Table 8 below).

Table 8: Reference cell in pavement cost structure matrix

TRH4			Base	B(100-80)		B(100-80)		B(100-80)		B(100-80)	
			Subbase			SB(125-25)		SB(125-25)		SB(125-25)	
			Selected							S(150-7)	
			Subgrade	NG25		NG15		NG7		NG3	
Traffic				Low (< 0.1 MESA)							
Subgrade				Very Good		Good (NG15)		Fair (NG7)		Poor (NG3)	
Moisture regime/ climate				Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	B(100-80N)	B(100-80N)	B(100-80N)	B(100-80N)	B(100-80N)	B(100-80N)	B(100-80N)	B(100-80N)
				No Import	No Import	SB(125-25N)	SB(125-25N)	SB(125-25N)	SB(125-25N)	SB(125-25N)	SB(125-25N)
				No Import	No Import	No Import	No Import	No Import	No Import	S(150-7N)	S(150-7N)
				No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
				RR	RR	RR	RR	RR	RR	RR	RR
			Low	B(100-80L)	B(100-80L)	B(100-80L)	B(100-80L)	B(100-80L)	B(100-80L)	B(100-80L)	B(100-80L)
				No Import	No Import	SB(125-25L)	SB(125-25L)	SB(125-25L)	SB(125-25L)	SB(125-25L)	SB(125-25L)
				No Import	No Import	No Import	No Import	No Import	No Import	S(150-7N)	S(150-7N)
				No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
				RR	RR	RR	RR	RR	RR	RR	RR
			Medium	B(100-80M)	B(100-80M)	B(100-80M)	B(100-80M)	B(100-80M)	B(100-80M)	B(100-80M)	B(100-80M)
				No Import	No Import	SB(125-15M)	SB(125-25M)	SB(125-25M)	SB(125-25M)	SB(125-25M)	SB(125-25M)
				No Import	No Import	No Import	No Import	No Import	No Import	S(150-15N)	S(150-15N)
				No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
				RR	RR	RR	RR	RR	RR	RR	RR
			High	B(100-80H)	B(100-80H)	B(100-80H)	B(100-80H)	B(100-80H)	B(100-80H)	B(100-80H)	B(100-80H)
				No Import	No Import	SB(125-25H)	SB(125-25H)	SB(125-25H)	SB(125-25H)	SB(125-25H)	SB(125-25H)
				No Import	No Import	No Import	No Import	No Import	No Import	S(150-15N)	S(150-15N)
				No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
				RR	RR	RR	RR	RR	RR	RR	RR

Note: (1) Zero, Low, Medium and High in column 4 refer to haulage distances; (2) RR = Rip and Recompact

By way of explanation:

(1) The base layer requires a CBR of 80. The available material (free haul) has a CBR=15. Therefore, the CBR=80 material must be imported. In this case, the haul distance is “Low” and an “L” is added after the 80

(2) The subbase layer requires a CBR of 25. The available material (free haul) has a CBR=15. Therefore, the CBR=25 material must be imported. In this case, the haul distance is “Low” and an “L” is added after the 25

(3) Note: It is acknowledged that the haul distances of the CBR=80 and CBR=25 material could be different. Although the spreadsheet allows the user to enter any distance notation, each variation results in doubling the number of situations for comparison

(4) The in-situ material has a CBR = 3 and requires importation of a material for the selected layer with CBR=15. The only available material (free haul) has a CBR = 15. Therefore, the CBR=15 material must be imported, but without haulage costs. In this case, the additional haul distance is "None" and an "N" is added after the 15

(5) No capping layer or earth works required. Therefore "No import" of an additional layer/s is required.

Pavement structures for the other design methods were also derived, based on the specific requirements of each of these methods.

3.3.4 Pavement construction costs

Utilising the unit construction costs presented in Table 4 above, the total cost of each possible pavement layer for all design methods may be calculated as illustrated in Table 9.

Table 9: Pavement layer costs (USD/m^3)

Exch. rate Rand -USD		12.00				Haul (m^{3}km) per distance category							
						1km free	1-10km	10-30km	30-100km				
	Layer	Total cost/ m2	Layer Thickness (m)	Ex BB/Crusher per m^3	Load & 1km freehaul	0	0.4167	0.3333	0.2917	Construction (Plant & Labour)/m^3			
						0	5	20	65	Base	Subbase	Sel/Fill	Rip&Comp
Base	B(100-55H)	3.07	0.1	1.79		0.00	0.00	0.00	18.96	9.91	0.00	0.00	0.00
	B(100-55L)	1.59	0.1	1.79	2.08	0.00	2.08	0.00	0.00	9.91	0.00	0.00	0.00
	B(100-55M)	2.04	0.1	1.79	2.08	0.00	0.00	6.67	0.00	9.91	0.00	0.00	0.00
	B(100-55N)	1.38	0.1	1.79	2.08	0.00	0.00	0.00	0.00	9.91	0.00	0.00	0.00
	B(100-65H)	3.34	0.1	1.90	2.08	0.00	0.00	0.00	18.96	10.45	0.00	0.00	0.00
	B(100-65L)	1.65	0.1	1.90	2.08	0.00	2.08	0.00	0.00	10.45	0.00	0.00	0.00
	B(100-65M)	2.11	0.1	1.90	2.08	0.00	0.00	6.67	0.00	10.45	0.00	0.00	0.00
	B(100-65N)	1.44	0.1	1.90	2.08	0.00	0.00	0.00	0.00	10.45	0.00	0.00	0.00
	B(100-80H)	3.44	0.1	2.08	2.08	0.00	0.00	0.00	18.96	11.25	0.00	0.00	0.00
	B(100-80L)	1.75	0.1	2.08	2.08	0.00	2.08	0.00	0.00	11.25	0.00	0.00	0.00
	B(100-80M)	2.21	0.1	2.08	2.08	0.00	0.00	6.67	0.00	11.25	0.00	0.00	0.00
	B(100-80N)	1.54	0.1	2.08	2.08	0.00	0.00	0.00	0.00	11.25	0.00	0.00	0.00
	B(120-45H)	3.69	0.12	1.67	2.08	0.00	0.00	0.00	18.96	8.02	0.00	0.00	0.00
	B(120-45L)	1.66	0.12	1.67	2.08	0.00	2.08	0.00	0.00	8.02	0.00	0.00	0.00
	B(120-45M)	2.21	0.12	1.67	2.08	0.00	0.00	6.67	0.00	8.02	0.00	0.00	0.00
	B(120-45N)	1.41	0.12	1.67	2.08	0.00	0.00	0.00	0.00	8.02	0.00	0.00	0.00
	B(120-55H)	3.76	0.12	1.79	2.08	0.00	0.00	0.00	18.96	8.48	0.00	0.00	0.00
	B(120-55L)	1.73	0.12	1.79	2.08	0.00	2.08	0.00	0.00	8.48	0.00	0.00	0.00

3.3.5 Determination of pavement structure costs

Using a "Look-up" function, the cost of each layer in the pavement structure, as determined from Table 9, may be obtained and the total cost of each pavement structure, per design method, can be calculated as shown in Table 10 in terms of the total costs per layer (USD/m^3) based on the material unit construction costs.

Table 10: Pavement layer costs (USD/m^3) per layer (TRH4 method, <0.1 MESA only)

TRH4	Base	B(100-80)	B(100-80)	B(100-80)	B(100-80)
	Subbase		SB(125-25)	SB(125-25)	SB(125-25)
	Selected				S(150-7)
	Subgrade	NG25	NG15	NG7	NG3

Traffic				**Low (< 0.1 MESA)**							
Subgrade				Very Good		Good (NG15)		Fair (NG7)		Poor (NG3)	
Moisture regime/ climate				Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54
				0.00	0.00	1.28	1.28	1.28	1.28	1.28	1.28
				0.00	0.00	0.00	0.00	0.00	0.00	1.38	1.38
				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
			Low	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
				0.00	0.00	1.54	1.54	1.54	1.54	1.54	1.54
				0.00	0.00	0.00	0.00	0.00	0.00	1.38	1.38
				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
			Medium	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21
				0.00	0.00	2.11	2.11	2.11	2.11	2.11	2.11
				0.00	0.00	0.00	0.00	0.00	0.00	1.38	1.38
				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
			High	3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.44
				0.00	0.00	3.65	3.65	3.65	3.65	3.65	3.65
				0.00	0.00	0.00	0.00	0.00	0.00	1.38	1.38
				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38

3.3.6 Comparison of total pavement costs/km

Table 11 shows the costs per design method per design scenario which are obtained by adding the costs of each pavement layer per design method for the selected scenarios. The cost ratios are shown in Table 12 (Note: Table 11 -Table 17 are extracts from the full hypothetical design spreadsheets presented in **Annex G**).

Table 11: Total pavement costs/km per design method per scenario (USD/km) (example)

Traffic					Low (< 0.1 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry -Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	2,438	12,188	2,438	12,188	11,375	12,188	11,375	12,188
				TRH4	12,458	12,458	20,786	20,786	20,786	20,786	29,724	29,724
				DCP-CBR	11,620	12,188	12,188	19,967	20,535	21,000	29,183	29,183
				ORN31	13,813	13,813	13,813	13,813	13,813	13,813	21,531	22,141
			Low	DCP-DN	2,438	14,219	2,438	14,219	11,375	14,219	11,375	14,219
				TRH4	13,813	13,813	23,833	23,833	23,833	23,833	32,771	32,771
				DCP-CBR	13,245	14,219	14,219	23,217	22,567	24,656	32,839	32,839
				ORN31	15,844	15,844	15,844	15,844	15,844	15,844	24,917	25,865
			Medium	DCP-DN	2,438	18,688	2,438	18,688	11,375	18,688	11,375	18,688
				TRH4	16,792	16,792	30,536	30,536	30,536	30,536	39,474	39,474
				DCP-CBR	16,820	18,688	18,688	30,367	27,035	32,700	40,883	40,883
				ORN31	20,313	20,313	20,313	20,313	20,313	20,313	32,365	34,057
			High	DCP-DN	2,438	30,672	2,438	30,672	11,375	30,672	11,375	30,672
				TRH4	24,781	24,781	48,513	48,513	48,513	48,513	57,451	57,451
				DCP-CBR	26,407	30,672	30,672	49,542	39,020	54,272	62,455	62,455
				ORN31	32,297	32,297	32,297	32,297	32,297	32,297	52,339	56,029

3.3.7 Comparison of total pavement cost ratios

Table 12 shows the ratio of total ***pavement cost ratios*** of the alternative design methods against the DCP-DN method for low design traffic (< 0.1 MESA).

Table 12: Pavement cost ratios of alternative design methods (< 0.1 MESA)

Traffic					Low (< 0.1 MESA)							
ORN31 subgrade class					V Good (S6)	V Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S6)	Poor S5)
Subgrade					Very Good (NG25/30)		Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	5.11	1.02	8.53	1.71	1.83	1.71	2.61	2.44
				DCP-CBR	4.77	1.00	5.00	1.64	1.81	1.72	2.57	2.39
				ORN31	5.67	1.13	5.67	1.13	1.21	1.13	1.89	1.82
			Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	5.67	0.97	9.78	1.68	2.10	1.68	2.88	2.30
				DCP-CBR	5.43	1.00	5.83	1.63	1.98	1.73	2.89	2.31
				ORN31	6.50	1.11	6.50	1.11	1.39	1.11	2.19	1.82
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	6.89	0.90	12.53	1.63	2.68	1.63	3.47	2.11
				DCP-CBR	6.90	1.00	7.67	1.63	2.38	1.75	3.59	2.19
				ORN31	8.33	1.09	8.33	1.09	1.79	1.09	2.85	1.82
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	10.17	0.81	19.90	1.58	4.26	1.58	5.05	1.87
				DCP-CBR	10.83	1.00	12.58	1.62	3.43	1.77	5.49	2.04
				ORN31	13.25	1.05	13.25	1.05	2.84	1.05	4.60	1.83

From Table 12, the general, tentative findings for low design traffic loading only indicate the following:

(1) The pavement cost ratios of the other methods versus the DCP-DN method are, in general, higher for the relatively low traffic loading, and in extreme cases, by up to factor of almost 20, depending on climate, subgrade strength and material haulage distance. Such large differences have been found in practice. See, for example, Annex 1 that pertains to the Wamwangi-Karate road in Kenya in which the DCP-DN method requires only ripping and recompacting of the existing wearing course material whereas TRH 4 requires the importation of two pavement layers.

(2) The pavement cost ratios of the other methods vs. the DCP-DN method are generally highest in dry-moderate climates at high haluage distances (30 – 100 km) and very good/good subgrade conditions, and are generally lowest in all climates, on fair-poor subgrades and at all haulage distances.

3.3.8 Comparison of total project costs/km

Table 13 shows the total project costs/km of the alternative design methods against the DCP-DN method. These costs include those for the pavement layers (Table 11) as well as all other items that normally make up the total cost of a project (Establishment, Traffic Accommodation, Drainage and Structures, Profit, etc.).

Table 13: Total project costs/km (USD) of alternative design methods (< 0.1 MESA)

Traffic					Low (< 0.1 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784
				TRH4	122,144	122,144	133,205	133,205	133,205	133,205	145,077	145,077
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004
			Low	DCP-DN	108,833	124,482	108,833	124,482	120,705	124,482	120,705	124,482
				TRH4	123,942	123,942	137,253	137,253	137,253	137,253	149,124	149,124
				DCP-CBR	123,188	124,482	124,482	136,434	135,570	138,345	149,214	149,214
				ORN31	126,640	126,640	126,640	126,640	126,640	126,640	138,691	139,951
			Medium	DCP-DN	108,833	130,418	108,833	130,418	120,705	130,418	120,705	130,418
				TRH4	127,899	127,899	146,156	146,156	146,156	146,156	158,027	158,027
				DCP-CBR	127,937	130,418	130,418	145,931	141,506	149,029	159,898	159,898
				ORN31	132,576	132,576	132,576	132,576	132,576	132,576	148,584	150,832
			High	DCP-DN	108,833	146,336	108,833	146,336	120,705	146,336	120,705	146,336
				TRH4	138,512	138,512	170,033	170,033	170,033	170,033	181,905	181,905
				DCP-CBR	140,671	146,336	146,336	171,401	157,424	177,682	188,551	188,551
				ORN31	148,494	148,494	148,494	148,494	148,494	148,494	175,115	180,016

The differences in total project costs/km are more easily displayed in terms of project cost ratios as presented below.

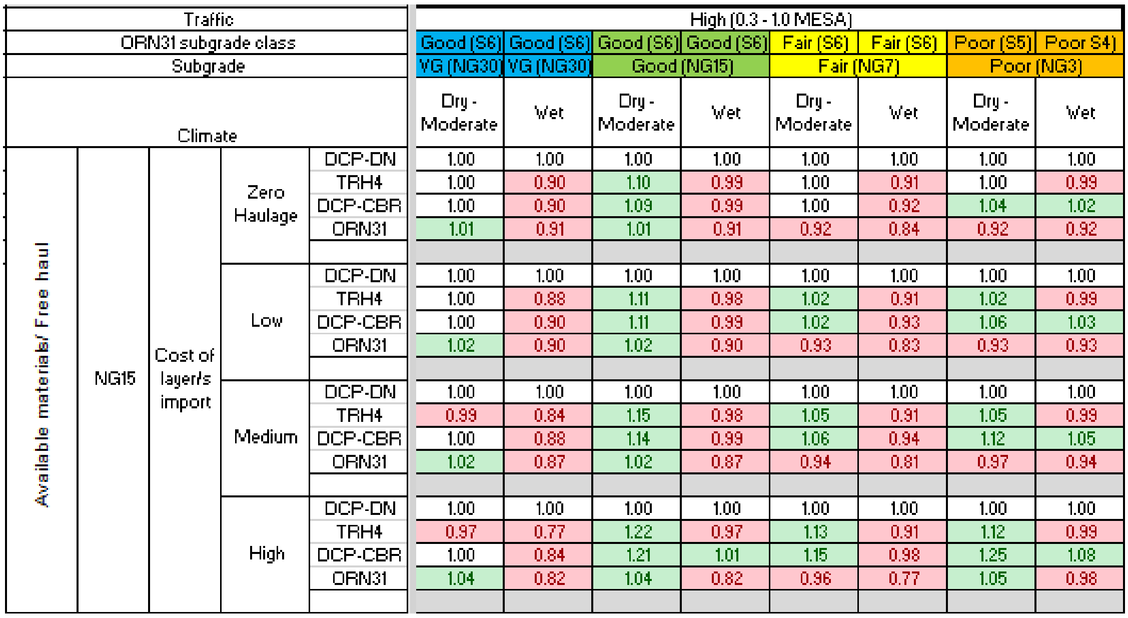
3.3.9 Comparison of project cost ratios for low and high design traffic

Table 14 and Table 15 show the project cost ratios for the low and high ends of the design traffic loading spectrum.

Table 14: Project cost ratios of alternative design methods (< 0.1 MESA)

Traffic					Low (< 0.1 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.22	1.09	1.10	1.09	1.20	1.19
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11
			Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.14	1.00	1.26	1.10	1.14	1.10	1.24	1.20
				DCP-CBR	1.13	1.00	1.14	1.10	1.12	1.11	1.24	1.20
				ORN31	1.16	1.02	1.16	1.02	1.05	1.02	1.15	1.12
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.18	0.98	1.34	1.12	1.21	1.12	1.31	1.21
				DCP-CBR	1.18	1.00	1.20	1.12	1.17	1.14	1.32	1.23
				ORN31	1.22	1.02	1.22	1.02	1.10	1.02	1.23	1.16
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.27	0.95	1.56	1.16	1.41	1.16	1.51	1.24
				DCP-CBR	1.29	1.00	1.34	1.17	1.30	1.21	1.56	1.29
				ORN31	1.36	1.01	1.36	1.01	1.23	1.01	1.45	1.23

Table 15: Project costs ratios of alternative design methods (0.3 – 1.0 MESA)



Traffic					High (0.3 - 1.0 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.00	0.90	1.10	0.99	1.00	0.91	1.00	0.99
				DCP-CBR	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.01	0.91	1.01	0.91	0.92	0.84	0.92	0.92
			Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.00	0.88	1.11	0.98	1.02	0.91	1.02	0.99
				DCP-CBR	1.00	0.90	1.11	0.99	1.02	0.93	1.06	1.03
				ORN31	1.02	0.90	1.02	0.90	0.93	0.83	0.93	0.93
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	0.99	0.84	1.15	0.98	1.05	0.91	1.05	0.99
				DCP-CBR	1.00	0.88	1.14	0.99	1.06	0.94	1.12	1.05
				ORN31	1.02	0.87	1.02	0.87	0.94	0.81	0.97	0.94
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	0.97	0.77	1.22	0.97	1.13	0.91	1.12	0.99
				DCP-CBR	1.00	0.84	1.21	1.01	1.15	0.98	1.25	1.08
				ORN31	1.04	0.82	1.04	0.82	0.96	0.77	1.05	0.98

From Table 14 and Table 15, general, tentative findings for low and high traffic loading scenarios can be drawn, as follows:

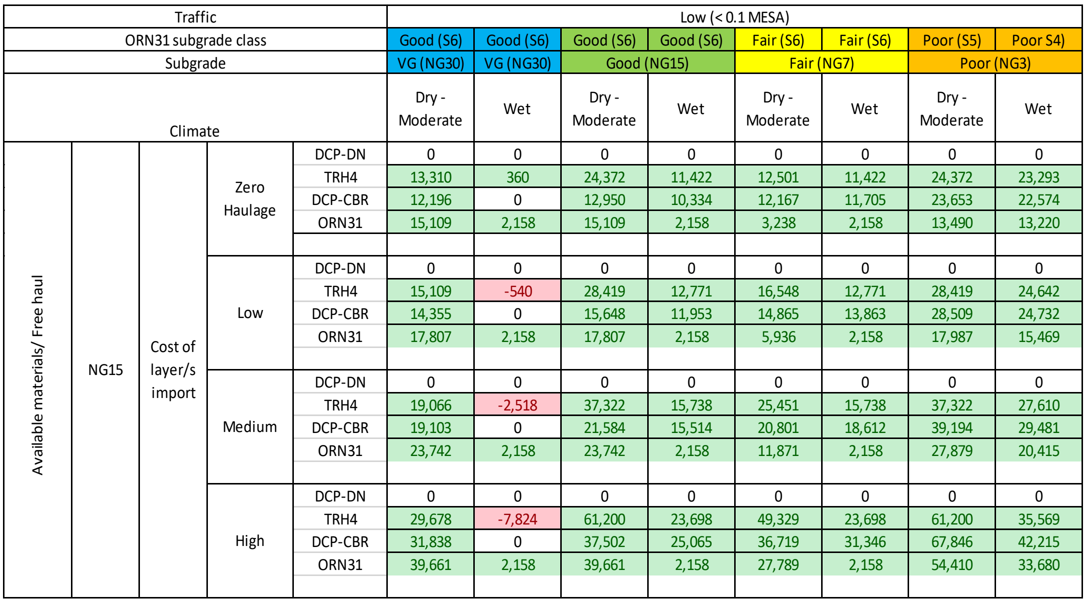
(1) In low design traffic situations (Table 14), the project costs of the DCP-DN method are generally lower than the other methods, by 14% to 56% in dry-moderate climates at high haulage situations (30 – 100 km) and poor subgrade conditions.

(2) In high design traffic situations (Table 15), the project costs of the DCP-DN method are generlly higher than the other design methods in wet climates across all haulage and subgrade conditions. In contrast, in dry-moderate climates and across all haulage and subgrade conditions, the other design methods generally exhibit higer project cost ratios.

3.3.10 Comparison of project cost savings/km for low and high design traffic

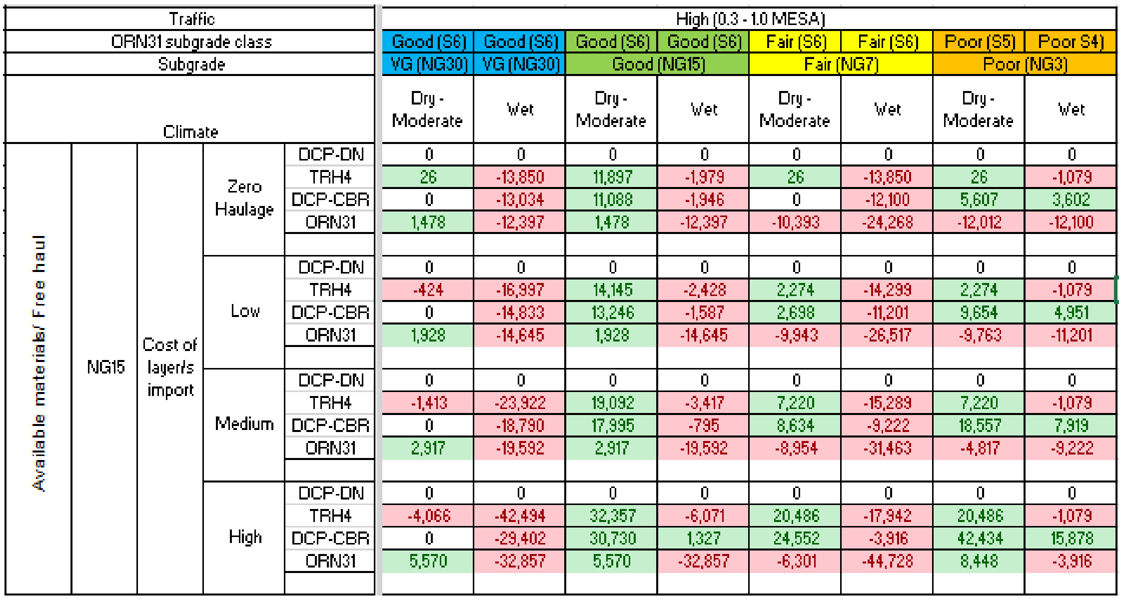
Table 16 and Table 17 show the project cost savings/km, which are generarlly of most interest to clients, for the low and high ends of the design traffic loading spectrum.

Table 16: Project cost savings/km (< 0.1 MESA)



Traffic					Low (< 0.1 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	13,310	360	24,372	11,422	12,501	11,422	24,372	23,293
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574
				ORN31	15,109	2,158	15,109	2,158	3,238	2,158	13,490	13,220
			Low	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	15,109	-540	28,419	12,771	16,548	12,771	28,419	24,642
				DCP-CBR	14,355	0	15,648	11,953	14,865	13,863	28,509	24,732
				ORN31	17,807	2,158	17,807	2,158	5,936	2,158	17,987	15,469
			Medium	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	19,066	-2,518	37,322	15,738	25,451	15,738	37,322	27,610
				DCP-CBR	19,103	0	21,584	15,514	20,801	18,612	39,194	29,481
				ORN31	23,742	2,158	23,742	2,158	11,871	2,158	27,879	20,415
			High	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	29,678	-7,824	61,200	23,698	49,329	23,698	61,200	35,569
				DCP-CBR	31,838	0	37,502	25,065	36,719	31,346	67,846	42,215
				ORN31	39,661	2,158	39,661	2,158	27,789	2,158	54,410	33,680

Table 17: Project cost savings/km (0.3 – 1.0 MESA)



Traffic					High (0.3 - 1.0 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	26	-13,850	11,897	-1,979	26	-13,850	26	-1,079
				DCP-CBR	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-12,012	-12,100
			Low	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	-424	-16,997	14,145	-2,428	2,274	-14,299	2,274	-1,079
				DCP-CBR	0	-14,833	13,246	-1,587	2,698	-11,201	9,654	4,951
				ORN31	1,928	-14,645	1,928	-14,645	-9,943	-26,517	-9,763	-11,201
			Medium	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	-1,413	-23,922	19,092	-3,417	7,220	-15,289	7,220	-1,079
				DCP-CBR	0	-18,790	17,995	-795	8,634	-9,222	18,557	7,919
				ORN31	2,917	-19,592	2,917	-19,592	-8,954	-31,463	-4,817	-9,222
			High	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	-4,066	-42,494	32,357	-6,071	20,486	-17,942	20,486	-1,079
				DCP-CBR	0	-29,402	30,730	1,327	24,552	-3,916	42,434	15,878
				ORN31	5,570	-32,857	5,570	-32,857	-6,301	-44,728	8,448	-3,916

From Table 16 and Table 17, general, tentative findings for low and high traffic loading scenarios can be drawn, as follows:

(1) In low design traffic situations, the project costs/km of the DCP-DN method are, in general, almost always lower, to varying extents, than the other design methods except in a few cases in wet climates across all haulage situations.

(2) In high design traffic situations, the project costs/km of the DCP-DN method are generally only lower than the other methods in dry-moderate climates across all haulage and subgrade situtions.

The above examples illustrate the procedure adopted to develop the hypothetical designs and, in so doing, they allow a few snap-shot conclusions to be drawn based on a very limited number of design scenarios. For illustration purposes, a full example is provided (**Annex G)** of the process followed to determine initially the project costs per km when designed using the different methods, and then the pavement cost ratios, total project cost ratios and total project cost difference per km.

3.3.11 General comparative cost trends

The full range of some 2304 design scenarios that could be encountered in practice is presented in the spreadsheets included in **Annex G** in terms of the following:

1. Pavement cost
2. Pavement cost ratios (DCP-DN versus other design methods)
3. Project costs
4. Project cost ratios (DCP-DN versus other design methods)
5. Project cost savings per km (DCP-DN versus other design methods)

For these analyses a pavement width of 6.50 m has been used to establish trends in the data for different traffic load classes, moisture environments and subgrade classes.

Hypothetical designs have been carried out, using four different design methods and costs calculated for three different design traffic scenarios (0.1, 0.3 and 1.0 MISA), in moderate to dry and wet environments, for four different subgrade conditions (In-situ subgrade CBRs of 3, 7, 15 and 25), for three different haul distances (low = 5km, medium = 20km and long = 65km) if only material of a specific quality is available i.e. CBR of 15, 30, 45, 55, 65 and 80. A zero haulage scenario was added for all combinations, assuming that all required materials are available within a free-haulage distance.

Graphical displays of the zero-haul distance costs (for all materials) and medium haul distance costs (assuming all materials better than CBR=15 must be imported) are provided adjacent to each other (see Figures 3 to 6) for the following situations namely:

- Pavement costs in the wet environment (Figure 3)
- Pavement costs in the moderate – dry environment (Figure 4)
- Project costs in the wet environment (Figure 5)
- Project costs in the moderate – dry environment (Figure 6)

Important notes on the zero-haulage scenario

As higher quality materials often have to be imported, provision was made to evaluate the cost of material haulage at three distances i.e. Low (5km), Medium (20km) and Long (65km).

The inclusion of the zero-haulage cost scenario effectively means that all materials required for any pavement structure are available within a free haulage distance (typically 1 km).

Cognizance should be taken that this scenario is considered unrealistic in most cases as suitable base quality materials e.g. CBR =80 for ORN31 and TRH4, even for very low volume roads, are normally not available close by. Moreover, for a LVR project of any significant length, say 10 km, it would be necessary to open 5 borrow pits immediately adjacent to the road at regular intervals, say at km 2, 4, 6, 8 and 10, in order not to exceed the free haul distance. This is practically unrealistic and would be environmentally unacceptable.

Furthermore, it should be noted that if provision is not made in a tender for haulage of different quality materials, the contractor will incorporate the haulage costs in the tendered unit cost. This means that the costs (Ex borrow pit or crusher) as obtained from contractors and incorporated in the hypothetical designs are actually not valid for the zero-haulage scenario.

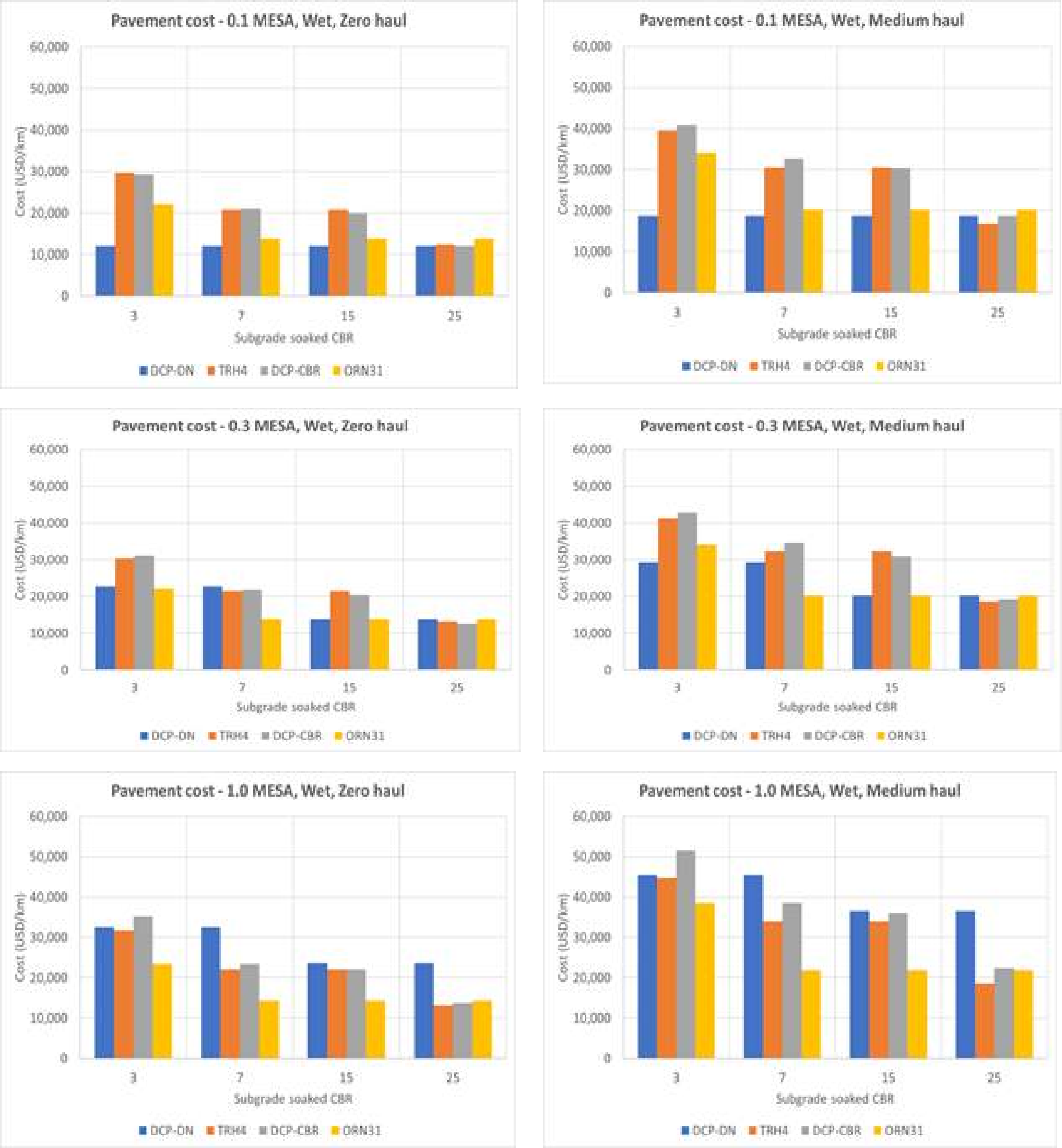


Figure 3: Pavement costs (Wet environment) – Zero versus Medium haul distance

In terms of pavement costs in the wet environment, DCP-DN is generally the most cost-effective for design traffic less than 1 MESA, on all but the strongest subgrades (CBR 25%), and regardless of the hauling distance. However, the relative difference in pavement costs between the DCP-DN and other design methods, is less with the zero-haulage scenario. For the 1 MESA scenario, ORN31 is generally the most cost-effective on all but the strongest (CBR 25%) subgrades for which TRH4 is the most cost-effective.

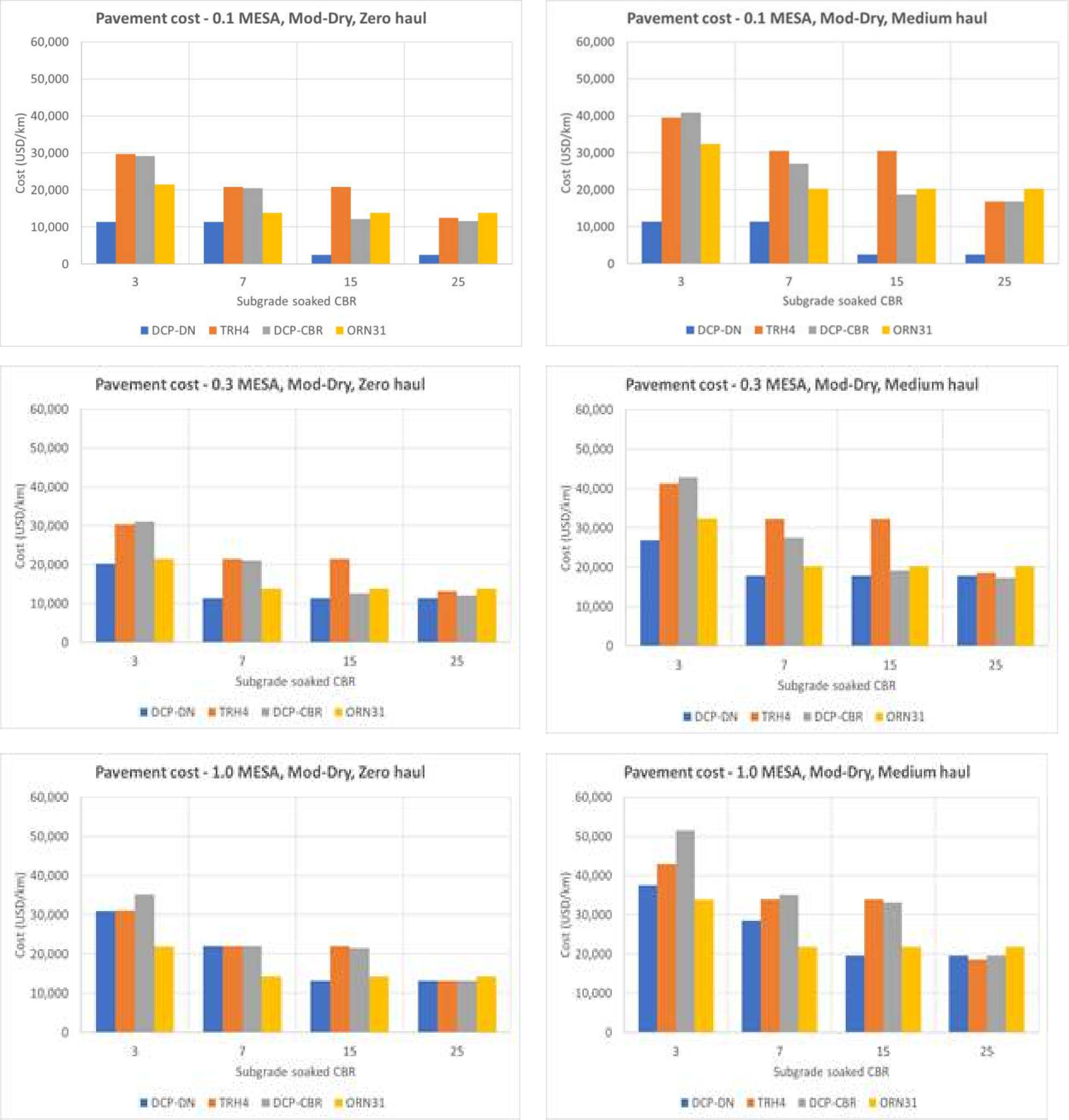


Figure 4: Pavement costs (Mod-Dry environment) – Zero versus Medium haul distance

In terms of pavement costs in the moderate to dry environment and medium haul distance, DCP-DN is generally the most cost-effective for all design traffic classes up to 1 MESA. For the zero-haul distance, DCP-DN is generally the most cost-effective for design traffic classes **less** than 1 MESA. However, the relative difference in pavement costs between the DCP-DN and other design methods, is less with the zero-haulage scenario. For the zero-haul distance and 1 MESA design traffic ORN31 is more cost-effective for fair to poor subgrades and DCP-DN more cost-effective for good quality subgrades.

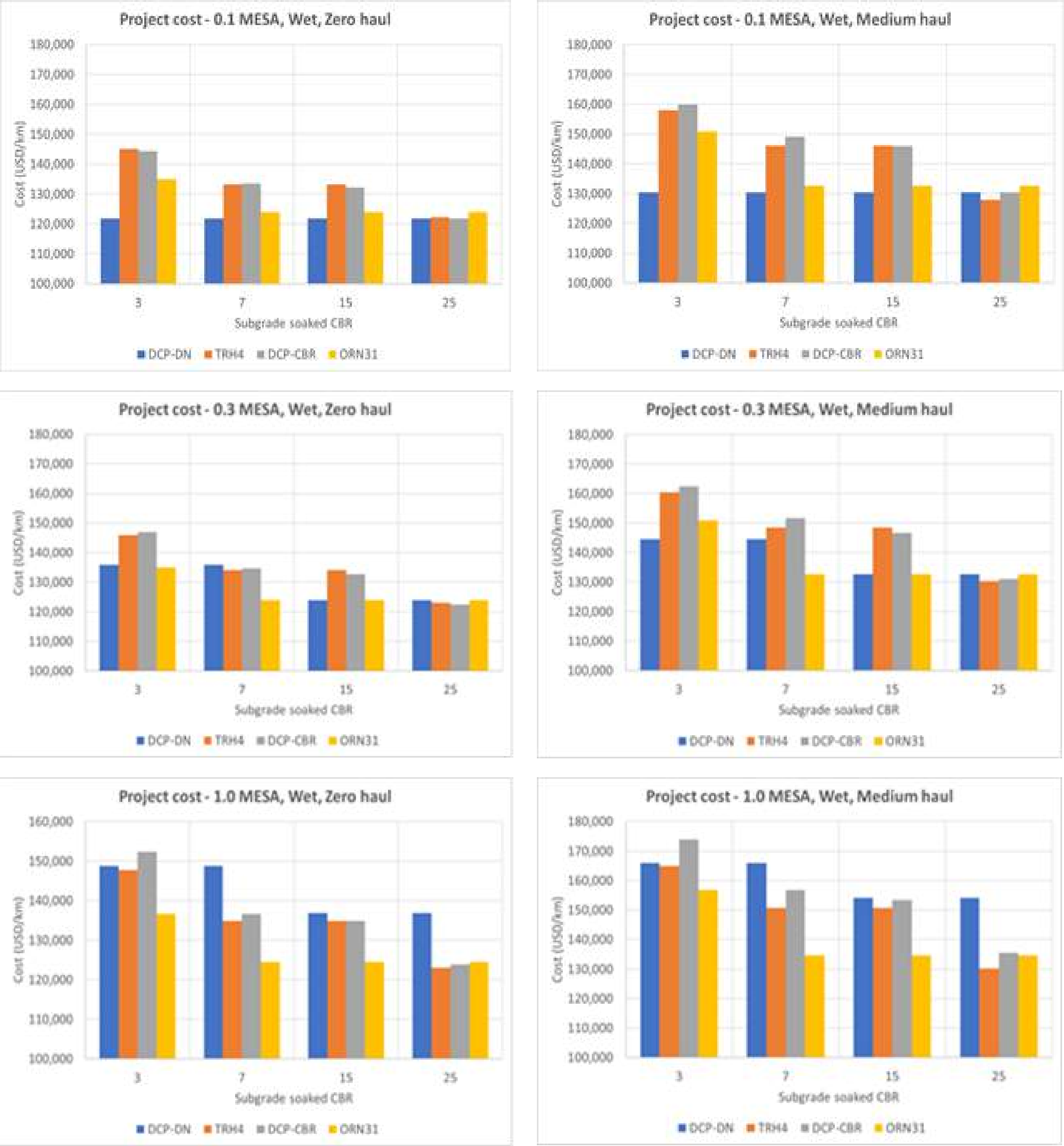


Figure 5: Project costs (Wet environment) – Zero versus Medium haul distance

In terms of project costs in the wet environment, DCP-DN is generally the most cost-effective for design traffic less than 1 MESA and on poor-fair subgrades, regardless of the hauling distance. However, the relative difference in project costs between the DCP-DN and other design methods, is less with the zero-haulage scenario. ORN31 is generally the most cost-effective for the 1 MESA scenario, except for the strong subgrades (CBR 25%).

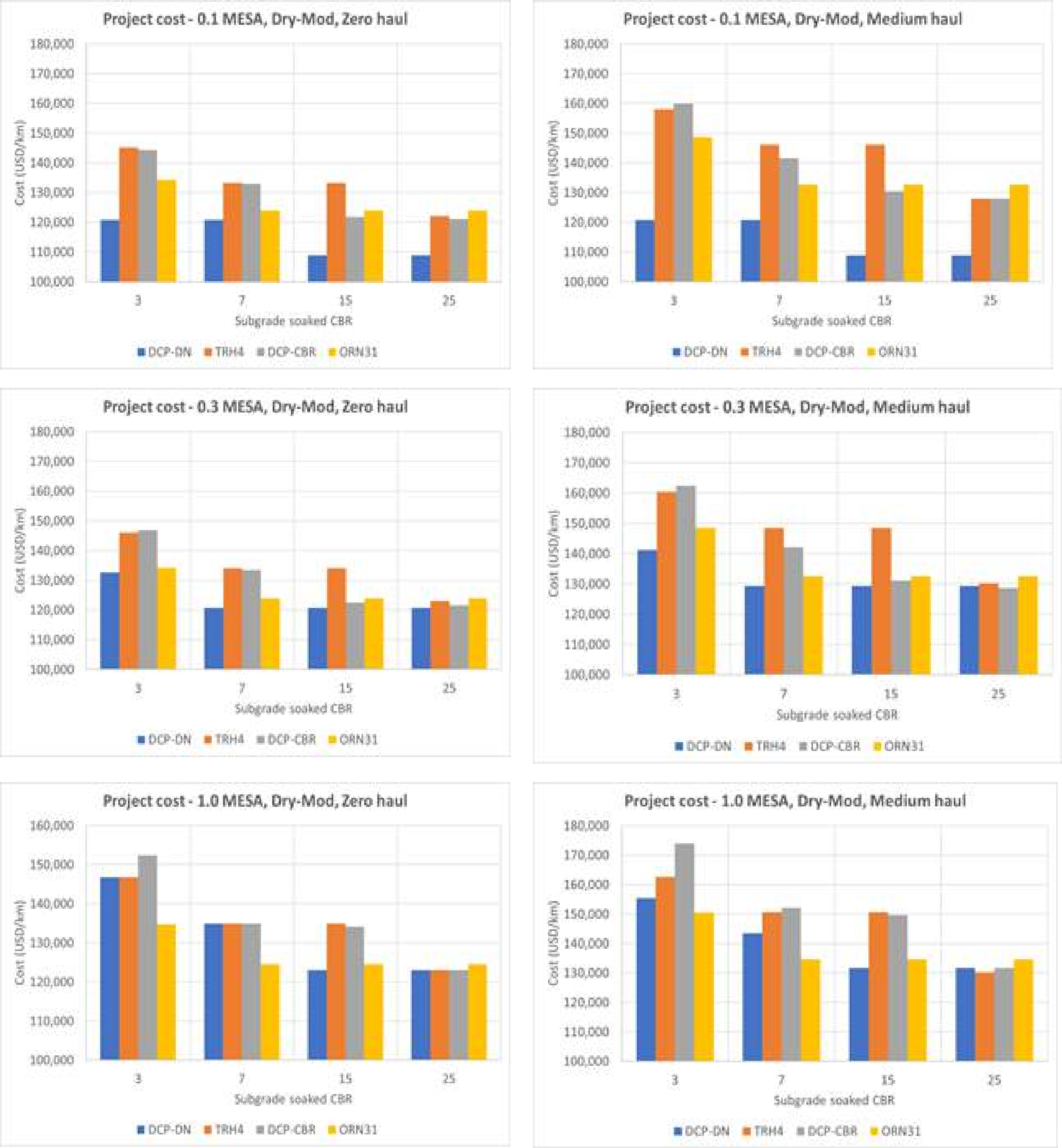


Figure 6: Project costs (Moderate-Dry environment) - Zero versus Medium haul distance

In terms of **project costs in the moderate to dry environment**, DCP-DN is generally the most cost-effective for design traffic less than 1 MESA, regardless of the hauling distance. However, the relative difference in project costs between the DCP-DN and other design methods, is less with the zero-haulage scenario. ORN31 is generally the most cost-effective for the 1 MESA scenario.

3.4 In-Situ Designs

3.4.1 General

The approach to the design of the road sections in the various countries differs between the four methods being considered. Thus, a typical design example is presented below to illustrate how the same input design data has been applied to all four design methods.

3.4.2 Design inputs

The design details are for the Zambia Katonga-Waitwika Trial Section and are as follows:

- **Traffic (MESA)**
    - Low: < 0.1 (TLC0.1)
- **In-situ subgrade**
    - In-situ moisture at time of survey (wet season):
        - 0 – 150 mm = OMC
        - 150 – 300 mm = 1.2 OMC
        - 300 – 450 mm = 1.35 OMC
- **Climatic zone**
    - Wet (N < 2) (annual rainfall 1050 mm)

3.4.3 DCP-DN design method

Details of this design method are outlined in Section 2.3.4 above. As indicated therein, the strength of the pavement layers and subgrade are all assessed at the anticipated long-term equilibrium moisture content (EMC). The representative subgrade strength in a uniform section is based on the 80th, 50th or 20th percentile value of the range of DCP measurements along that section of the road being upgraded depending on whether the EMC is likely, respectively, to be wetter, about the same or drier than at the time of the DCP survey.

In the design example, it is assumed that after upgrading of the road, provision of adequate drainage and surfacing from shoulder breakpoint to shoulder breakpoint, the relative moisture content in the top three layers of the existing road will equilibrate at or below OMC (Ref. Section 2.4.5 based on Emery, 1985 – **Annex E).**

- **Design**

On the basis of the above assumption, the DN values for design were adjusted as follows:

- 0-150 mm DN(50P) = 16 (moisture in layer remaining at OMC)
- 150-300 mm DN (20P) = 26 (moisture in layer decreasing)
- 300-450 mm DN (20P) = 37 (moisture in layer decreasing)

- **Material Quality**

The material quality requirements are specified in the DCP structural design catalogue for TLC 0.1 as follows:

- Base: DN ≤ 4 at long-term EMC
- Subbase: DN ≤ 9 at long-term EMC
- Subgrade: DN ≤ 19 at long-term EMC

- **Pavement structure**

The pavement structure requirements for the upgraded road are presented in Figure 7.

3.4.4 TRH4 design method

Details of this design method are outlined in Section 2.3.6 above. As indicated therein, the strength of the pavement layers and subgrade materials are all assessed in their soaked condition, but the pavement structure requirements are less demanding in dry-moderate climates. The representative subgrade strength in a uniform section is based on the 90th percentile value of the range of CBR or, more likely, the 10th percentile DCP values obtained from a survey along the section of the road being upgraded.

- **In-situ subgrade**
    - 0-150 mm: Weighted Average DN = 16 at OMC. For input into the TRH4 design, this value must be converted to an equivalent soaked CBR value using the 10th percentile DN value.
- **Design**
    - Based on the Kleyn DCP-CBR correlation and the use of Table 2, DN = 16 at OMC converts to a soaked CBR value of < 3 (< NG3). This strength of subgrade requires the use of an overlying capping layer.
- **Material Quality**

The material quality requirements are specified in the TRH4 structural design catalogue for TLC 0.1 as follows:

- Base: soaked CBR ≥ 80
- Subbase: soaked CBR ≥ 25
- Capping layer: soaked CBR ≥ 7

- **Pavement structure**

The pavement structure requirements for the upgraded road are presented in Figure 7

3.4.5 ORN31 design method

Details of this design method are outlined in Section 2.3.7 above. As indicated therein, the strength of the pavement layers and subgrade materials are all assessed in their soaked condition, and the pavement structure requirements are the same, regardless of climatic zone. However, the subgrade strength may be assessed in the soaked state (Category 1), at OMC (Category 2) or below OMC (Category 3), depending on the proximity of the water table to the subgrade and the annual rainfall (> 250 mm for Category 2 subgrades and < 250 mm for Category 3 subgrades). The representative subgrade strength in a uniform section is based on the 90th percentile value of the range of CBR or, more likely, DCP measurements along that section of the road being upgraded.

- **In-situ subgrade**
    - Assumed to be Category 2, based on a low water table and annual rainfall of 1050 mm.
- **Design**
    - On the basis of the above assumption, the DN values for design are converted to CBR values based on the TRL correlation between DCP and CBR.
        - The DN(10P) = 20 at OMC corresponds to CBR_{OMC} = 14.
        - Subgrade Class: S4
- **Material Quality**

The material quality requirements are specified in the ORN31 structural design catalogue for TLC 0.1 as follows:

- Base: soaked CBR ≥ 80
- Subbase: soaked CBR ≥ 25

- **Pavement structure**

The pavement structure requirements for the upgraded road are presented in Figure 7DCP-CBR design method

Details of this design method are outlined in Section 2.3.5 above. As indicated therein, the strength of the pavement layers and subgrade materials are all assessed in their soaked condition. However, the pavement structure requirements are less demanding in dry-moderate climates. For TLC < 0.3 MESA, the representative subgrade strength in a uniform section is based on the mean value of the range of CBR or, more likely, DCP measurements obtained from a survey along the section of the road being upgraded.

- **In-situ subgrade**
  - 0-150 mm: DN = 16 at OMC. For input into the DCP-CBR design, this value must be converted to an equivalent soaked CBR value. Based on the TRL DCP-CBR correlation and the use of Table 2, DN = 16 at OMC converts to a soaked CBR value of < 3 (as per ORN31). This strength of subgrade requires the use of an overlying capping layer.
- **Design**
  - Based on the TRL DCP-CBR correlation and the use of Table 2, DN = 16 at OMC converts to a soaked CBR value of <3. This strength of subgrade requires the use of an overlying capping layer.
- **Material Quality**

The material quality requirements are specified in the DCP-CBR structural design catalogue for TLC 0.3 MESA as follows:

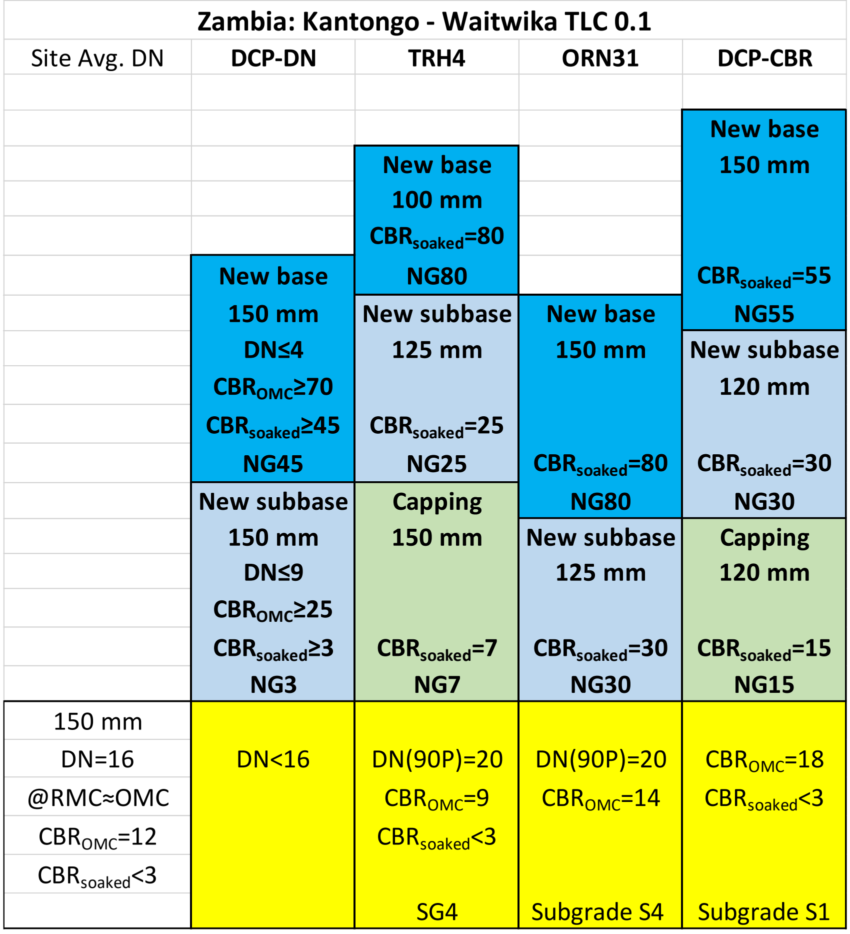
  - Base: soaked CBR ≥ 55
  - Subbase: soaked CBR ≥ 30
  - Capping layer: soaked CBR ≥ 15

- **Pavement structure**

The pavement structure requirements for the upgraded road are presented in Figure 7

3.4.6 Determination of pavement structure

The pavement structures derived from the same input data applied to the four design methods described above are presented in Figure 7. These structures are based on the use of the same design input information that, in part, has been adjusted for the subgrade strength requirements (soaked/unsoaked) and representative percentile-related strength values, as required by the various methods. Similar pavement structures and related pavement costs have been derived for all road sections and are presented in **Annex I.**



Zambia: Kantongo - Waitwika TLC 0.1				
Site Avg. DN	**DCP-DN**	**TRH4**	**ORN31**	**DCP-CBR**
	New base 150 mm DN≤4 CBR_{OMC}≥70 CBR_{soaked}≥45 NG45	**New base 100 mm CBR_{soaked}=80 NG80**	**New base 150 mm CBR_{soaked}=80 NG80**	**New base 150 mm CBR_{soaked}=55 NG55**
	New subbase 150 mm DN≤9 CBR_{OMC}≥25 CBR_{soaked}≥3 NG3	**New subbase 125 mm CBR_{soaked}=25 NG25**	**New subbase 125 mm CBR_{soaked}=30 NG30**	**New subbase 120 mm CBR_{soaked}=30 NG30**
		Capping 150 mm CBR_{soaked}=7 NG7		**Capping 120 mm CBR_{soaked}=15 NG15**
150 mm DN=16 @RMC≈OMC CBR_{OMC}=12 CBR_{soaked}<3	DN<16	DN(90P)=20 CBR_{OMC}=9 CBR_{soaked}<3 SG4	DN(90P)=20 CBR_{OMC}=14 Subgrade S4	CBR_{OMC}=18 CBR_{soaked}<3 Subgrade S1

Figure 7: Comparison of pavement structures by design methods for TLC 0.1 & NG3

3.4.7 *Determination of pavement structure costs*

For illustrative purposes, Zambian cost data was applied to the pavement structures presented in Figure 7 as shown in Table 18.

Table 18: Pavement structure costs based on Zambian cost data

Cost for 6.5 m wide pavement incl. 100 mm rip, shape and recompact of in situ wearing course

USD/km

		Zero haulage		32520
DCP-DN		**Base 150 mm NG25**		
Avg. haul km		**5**	**20**	**65**
Subbase 150 mm G10	**5**	36 517	39 978	51 630
	20	39 978	43 440	55 091
	65	51 630	55 091	66 742

		Zero haulage		38796
ORN31		**Base 150 mm NG80**		
Avg. haul km		**5**	**20**	**65**
Subbase 150 mm NG30	**5**	42 793	46 254	57 906
	20	46 254	49 716	61 367
	65	57 906	61 367	73 018

		Zero haulage		42305
TRH4		**Base 100 mm NG80**		
Avg. haul km		**5**	**20**	**65**
150 mm NG7 + Subbase 125 mm NG25	**5**	47 302	49 610	57 377
	20	53 648	55 955	63 723
	65	75 008	77 316	85 083

		Zero haulage		47949
DCP-CBR		**Base 150 mm NG55**		
Avg. haul km		**5**	**20**	**65**
120 mm NG15 + Subbase 120 mm NG30	**5**	53 145	56 607	68 258
	20	58 683	62 145	73 796
	65	77 325	80 787	92 438

3.4.8 Pavement cost ratios

Table 19 and Table 20 show the pavement cost ratios for the different design methods and TLCs. As mentioned above, Zambian cost data are used for the Zambia example. However, South African costs data were used for Ghana and Kenya due to the lack of disaggregated material costs for these countries.

Table 19 shows the pavement cost ratios for three actual projects designed for TLC 0.1. The large differences in the cost ratios are mainly due to the assessment of the subgrade strength as prescribed for the different design methods. Whereas TRH4 and ORN31 prescribe the use of the 90th percentile of the subgrade strength within the section, DCP-DN and DCP-CBR require the use of the mean value. ORN31 also allows the subgrade strength to be assessed at OMC which results in the ORN31 design being almost on par with the DCP-DN design.

Table 19: In-situ pavement cost ratios

	Cost ratios USD/km for 6.5 m wide pavement														
	TLC 0.1														
	Climate		Subgrade	< NG3		Climate		Subgrade	NG7		Climate		Subgrade	NG45	
	Wet		Zambia			Wet		Ghana			Wet		Kenya		
Design method	Average haul (km)		Base			Average haul (km)		Base			Average haul (km)		Base		
			5	20	65			5	20	65			5	20	65
DCP-DN	Subbase & Capping layer	5	1,00	1,00	1,00	Subbase & Capping layer	5	1,00	1,00	1,00	Subbase & Capping layer	5	1,00	1,00	1,00
		20	1,00	1,00	1,00		20					20			
		65	1,00	1,00	1,00		65					65			
TRH4		5	1,44	1,32	1,12		5	2,39	1,98	1,47		5	9,78	11,00	14,28
		20	1,50	1,39	1,19		20	2,97	2,42	1,73		20	11,00	12,53	15,81
		65	1,60	1,51	1,33		65	4,51	3,59	2,45		65	15,40	16,63	19,90
ORN31		5	1,10	1,08	1,06		5	1,11	1,17	1,31		5	5,67	6,89	10,17
		20	1,06	1,05	1,04		20					20			
		65	0,99	0,99	0,99		65					65			
DCP-CBR		5	1,47	1,39	1,28		5	1,54	1,33	1,07		5	1,00	1,00	1,00
		20	1,49	1,42	1,31		20	1,80	1,53	1,19		20			
		65	1,52	1,47	1,37		65	2,50	2,06	1,52		65			

Key:	Ratio < 1	Ratio = 1	1 < Ratio ≤ 2	2 < Ratio ≤ 5	5 < Ratio ≤ 10	Ratio > 10

Table 20 shows the pavement costs ratios for the Ghana project for the TLC classes in the range 0.3 to 1.0 MESA. The results corroborate the overall trends from the hypothetical analysis discussed above with the cost ratios generally decreasing for increasing TLCs.

Table 20: In-situ pavement cost ratios for different TLCs

	Cost ratios USD/km for 6.5 m wide pavement														
	TLC 0.3					TLC 0.7					TLC 1.0				
	Climate		Subgrade	NG7		Climate		Subgrade	NG7		Climate		Subgrade	NG7	
	Wet		Ghana			Wet		Ghana			Wet		Ghana		
Design method	Average haul (km)		Base			Average haul (km)		Base			Average haul (km)		Base		
			5	20	65			5	20	65			5	20	65
DCP-DN	Subbase & Capping layer	5	1,00	1,00	1,00	Subbase & Capping layer	5	1,00	1,00	1,00	Subbase & Capping layer	5	1,00	1,00	1,00
		20					20					20	1,00	1,00	1,00
		65					65					65	1,00	1,00	1,00
TRH4		5	2,46	1,91	1,26		5	2,33	1,89	1,33		5	1,38	1,32	1,23
		20	3,04	2,31	1,47		20	2,90	2,30	1,55		20	1,47	1,41	1,31
		65	4,58	3,39	2,04		65	4,41	3,39	2,15		65	1,62	1,56	1,45
ORN31		5	1,11	1,08	1,04		5	1,00	1,00	1,00		5	0,62	0,70	0,83
		20					20					20			
		65					65					65			
DCP-CBR		5	1,82	1,53	1,17		5	1,78	1,55	1,24		5	1,05	1,09	1,16
		20	2,07	1,71	1,26		20	2,06	1,76	1,36		20	1,04	1,08	1,14
		65	2,75	2,18	1,51		65	2,81	2,30	1,65		65	1,03	1,06	1,11

Key:	Ratio < 1	Ratio = 1	1 < Ratio ≤ 2	2 < Ratio ≤ 5	5 < Ratio ≤ 10	Ratio > 10

As shown in Figure 8: Pavement cost ratios 'R'/km per TLC and Figure 9, the pavement cost ratios vs. the DCP-DN method are highest for the lower (TLCs 0.1 - 0 0.3 MESA) and begin to gradually decrease up to about 0.7 MESA, after which other design methods, particularly ORN31, become more cost-effective.

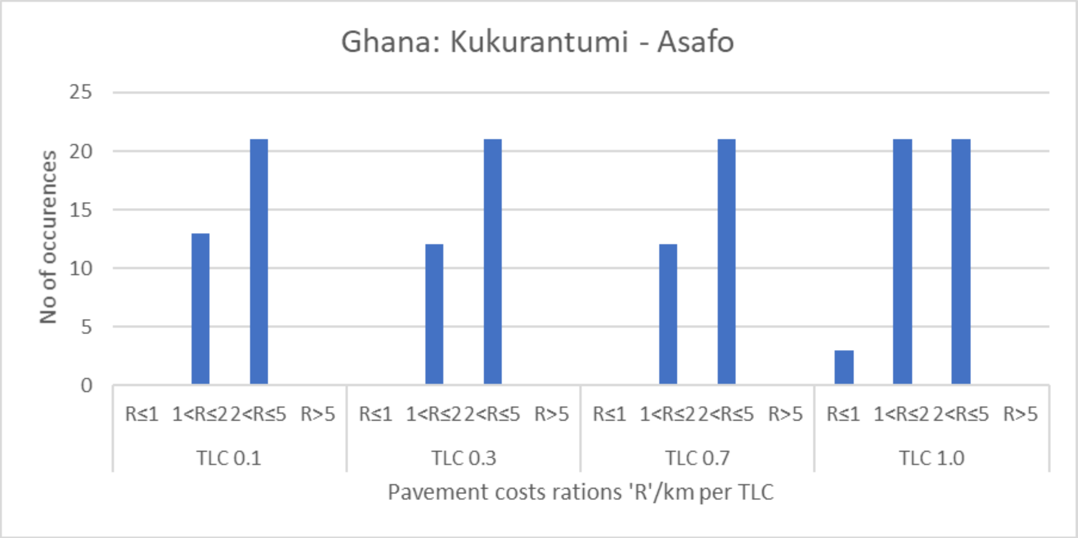


Figure 8: Pavement cost ratios 'R'/km per TLC

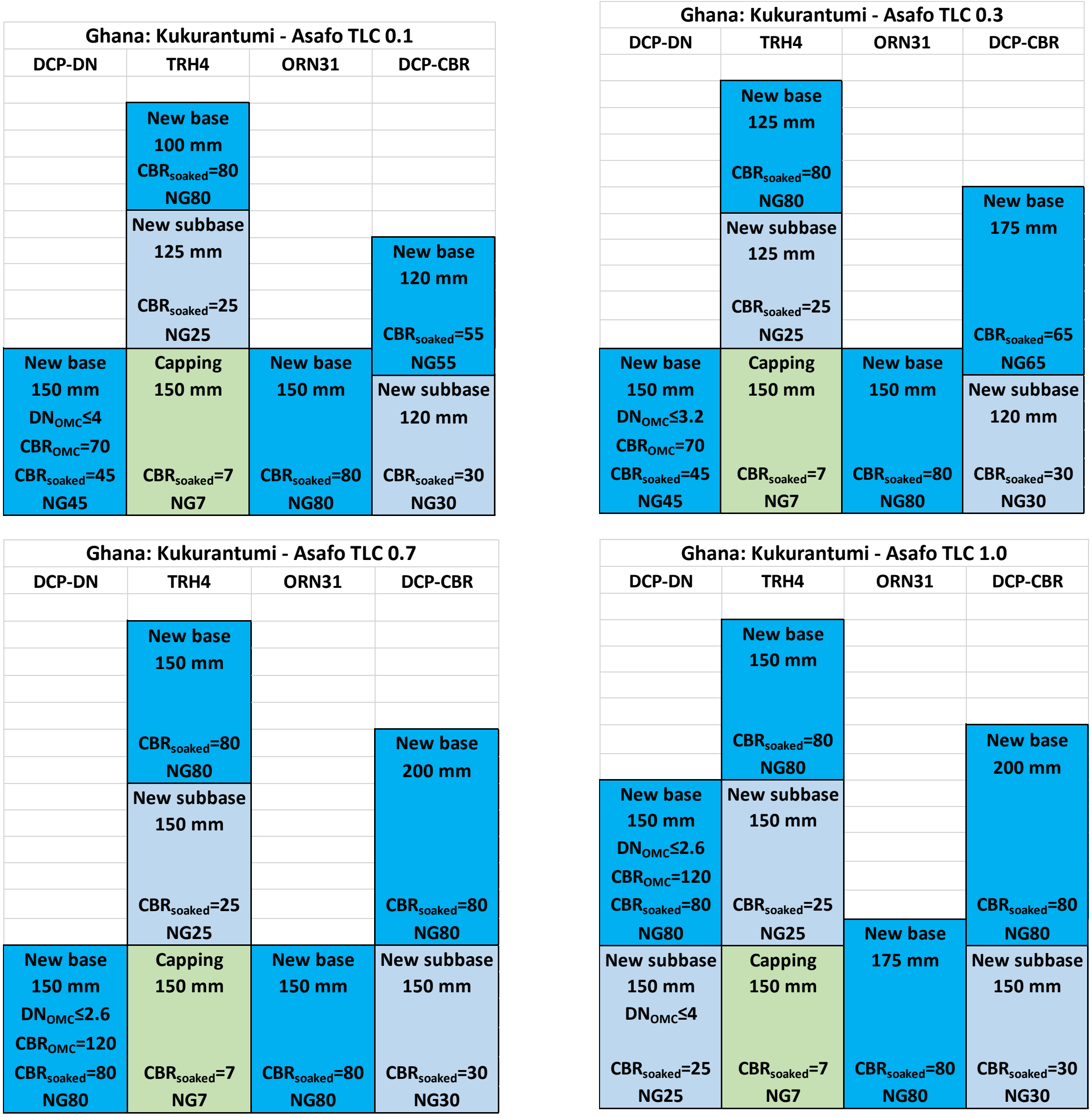


Figure 9: Kukurantumi - Asafo pavement structures by TLCs for different design methods

3.4.9 Project costs

The project costs were derived from the Zambian project by using the most likely haulage scenarios as per Table 18 (yellow cells) and as explained in Table 21, while keeping all other cost factors constant.

Table 21: Material haulage scenarios

Haulage scenario	Explanation
Short/short	Both Capping/Subbase and Base within average haul of 5 km
Short/medium	Capping/subbase at average haul of 5 km, base at average haul of 20 km
Short/Long	Capping/subbase at average haul of 5 km, base at average haul of 65 km
Medium/medium	Both Capping/subbase and base at average haul of 20 km
Medium/long	Capping/subbase at average haul of 20 km, base at average haul of 65 km
Long/long	Both Capping/subbase and base at average haul of 65 km

The resulting project costs for the various haulage scenarios are shown in Table 22.

In practice, for the long/long haul scenarios, some form of material improvement (chemical stabilisations, blending etc.), for the base only or for all pavement layers may provide more cost-effective solutions. However, this option is beyond the scope of these analyses.

Table 22: Project costs/km (USD) for various haulage scenarios

Project costs (USD) Kantogo - Waitwika, Zambia				
Haul scenarios	**DCP-DN**	**TRH4**	**ORN31**	**DCP-CBR**
Short/short	281 087	294 296	281 087	294 296
Short/medium	277 495	289 784	285 503	298 713
Short/long	292 362	299 696	300 370	313 580
Medium/medium	289 920	305 779	289 920	305 779
Medium/long	296 778	307 793	304 787	320 646
Long/long	319 654	344 433	319 654	344 433

3.4.10 Project cost ratios

The resulting project cost ratios in Table 23 show that for all haulage scenarios, the DCP-DN design method comes out cheaper than TRH4 and DCP-CBR with a margin of 2-12%. The ORN31 design is just marginally more expensive for all scenarios except for the medium/medium where it is on par with DCP-DN and the long/long combination in which it is marginally cheaper (see red cell).

Table 23: Project costs ratios for various haulage scenarios

Project cost ratios Kantogo – Waitwika, Zambia				
Haul scenarios	**DCP-DN**	**TRH4**	**ORN31**	**DCP-CBR**
Short/short	1.00	1.05	1.00	1.05
Short/medium	1.00	1.04	1.03	1.08
Short/long	1.00	1.03	1.03	1.07
Medium/medium	1.00	1.05	1.00	1.05
Medium/long	1.00	1.04	1.03	1.08
Long/long	1.00	1.08	1.00	1.08

3.4.11 Project cost differences

Table 24 shows that, based on the Zambia pavement and project costs, the DCP-DN design method offers considerable project cost savings/km in all haulage scenarios compared to TRH4 and DCP-CBR. ORN 31 is marginally more expensive in five of the haulage scenarios but offers slight project costs/km savings in the long/long haulage scenario.

Table 24: Project costs differences/km (USD) for various haulage scenarios

Project costs differences (%) Kantogo - Waitwika, Zambia				
Haul scenarios	**DCP-DN**	**TRH4**	**ORN31**	**DCP-CBR**
Short/short	-	13 209	-	13 209
Short/medium	-	12 290	8 008	21 218
Short/long	-	7 334	8 008	21 218
Medium/medium	-	15 859	-	15 859
Medium/long	-	11 014	8 008	23 868
Long/long	-	24 780	-	24 780

3.5 Hypothetical versus In-Situ Designs

3.5.1 Hypothetical designs

The hypothetical approach offers the possibility of determining the likely pavement and project cost ratios as well as the total project cost difference/km arising from the use of the various design methods when applied in a variety of situations pertaining to a range of design traffic loadings, subgrade strengths, climatic zones material haulage distances etc. Thus, it covers virtually all possible scenarios that could be met in practice. The materials costs and materials haulage rates have been obtained from contractors operating in a competitive environment in South Africa and provide a realistic basis for determining both the pavement layer costs and the related pavement structure costs from which the total project cost per design scenario and project cost difference/km have been derived.

The pavement and project cost ratio trends, as well as the total project cost difference/km for the various design methods provide valuable information in terms of which design method is best suited for application in particular road environment situation.

3.5.2 In-situ designs

The in-situ designs are based on actual design information pertaining to the 10 road sections located in six countries in west, east and southern Africa. For cost comparison with the hypothetical designs, the same cost information has been used, i.e. as obtained from South African contractors. However, where the information was available in the required format (Zambia, Tanzania and South Africa), cost ratios using the country-specific information were also calculated. Not surprisingly, since the same costs have been applied to the different design methods, this did not change the cost-ratio trends determined from the South African costs data.

3.5.3 Comparison of hypothetical and in-situ situ designs

Comparison of the pavement structure costs and related cost ratios for the 36 in-situ designs with those derived for the same road environmental conditions in the hypothetical cost matrix are generally similar, and a perfect match in cases where the in-situ conditions of projects are exactly the same as evaluated in the hypothetical designs. Table 25 provides evidence of such a case, with cost ratios similar for different traffic design loading and haul distances.

Table 25: Comparison of pavement cost ratios (Project versus Hypothetical)

Danger Point												
TLC	0.1 MESA				0.3 MESA				1.0 MESA			
Climate	Moderate/Dry				Moderate/Dry				Moderate/Dry			
Subgrade	CBR$_{0.75OMC=110}$	CBR$_{soaked=40}$	SG class $_{S6}$	SG class $_{S6}$	CBR$_{0.75OMC=110}$	CBR$_{soaked=40}$	SG class $_{S6}$	SG class $_{S6}$	CBR$_{0.75OMC=11}$	CBR$_{soaked=40}$	SG class $_{S6}$	SG class $_{S6}$
	Short haul				Short haul				Short haul			
	DCP-DN	TRH4	ORN31	DCP-CBR	DCP-DN	TRH4	ORN31	DCP-CBR	DCP-DN	TRH4	ORN31	DCP-CBR
Pavement cost ratio	1.00	5.67	6.50	5.43	1.00	6.08	6.50	5.62	1.00	0.98	1.10	1.05
Synthetic ratio	1.00	5.67	6.50	5.43	1.00	6.08	6.50	5.62	1.00	0.98	1.10	1.05
	Medium haul				Medium haul				Medium haul			
	DCP-DN	TRH4	ORN31	DCP-CBR	DCP-DN	TRH4	ORN31	DCP-CBR	DCP-DN	TRH4	ORN31	DCP-CBR
Pavement cost ratio	1.00	6.89	8.33	6.90	1.00	7.61	8.33	7.09	1.00	0.95	1.11	1.08
Synthetic ratio	1.00	6.89	8.33	6.90	1.00	7.61	8.33	7.09	1.00	0.95	1.11	1.08
	Long haul				Long haul				Long haul			
	DCP-DN	TRH4	ORN31	DCP-CBR	DCP-DN	TRH4	ORN31	DCP-CBR	DCP-DN	TRH4	ORN31	DCP-CBR
Pavement cost ratio	1.00	10.17	13.25	10.83	1.00	11.71	13.25	11.02	1.00	0.90	1.13	1.11
Synthetic ratio	1.00	10.17	13.25	10.83	1.00	11.71	13.25	11.02	1.00	0.90	1.13	1.11

As discussed in Section 3.5.2 above, the cost ratio trends derived from the in-situ designs have also been corroborated by the trends derived from the hypothetical design evaluations.

3.5.4 Implications of EMC selection

The type of pavement structure resulting from the application of the DCP-DN method is highly dependent on the designer's assumptions regarding the expected equilibrium moisture content of the pavement layers and the subgrade. As indicated in the penultimate paragraph of Section 2.4.1, it has been assumed conservatively that, even though the EMC in the pavement layers and subgrade could be expected to equilibrate below OMC (Emery, 1985), for design purposes the OMC has been adopted. The implication of this assumption is that there would be a built-in factor of safety in the design to cater for less than adequate maintenance of side drains that might result in slightly increased moisture contents in the subgrade and pavement layers. Should this not be a concern, then EMC design could be adopted that would result in thinner/less costly pavements, albeit with some degree of additional risk.

4 Evaluation of Value for Money

4.1 General

The UK Department for International Development (DFID) defines Value for Money (VFM) as "maximising the impact of each pound spent to improve poor people's lives" (DFID, 2011). This echoes the UK National Audit Office's definition which defines VFM as being "the optimal use of resources to achieve intended outcomes". A key element in both definitions is to make the best use of available resources to achieve sustainable outputs and outcomes.

4.2 Framework for VFM analysis

The VFM conceptual framework is based on a logical "results chain" which explicitly sets out the results to be achieved by a given programme or project. **Error! Reference source not found.** presents the five main elements of this results chain and shows where the four main dimensions of VFM can be measured.

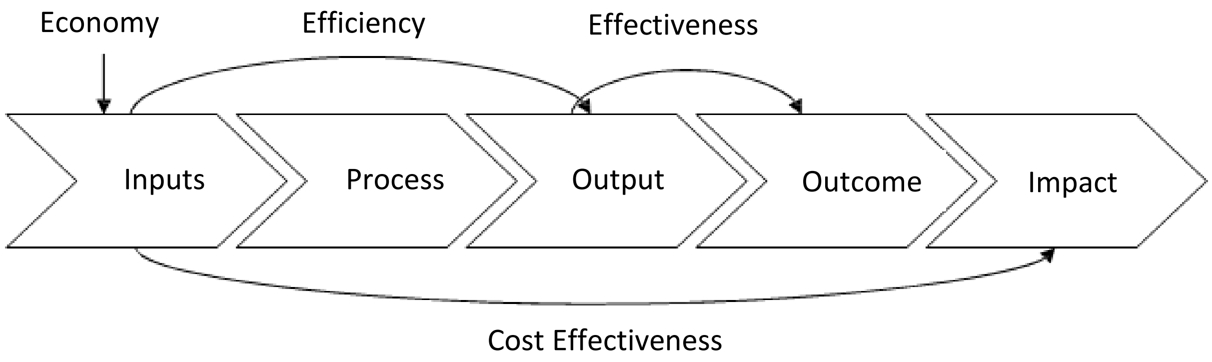


Figure 10: Framework for VFM analysis (DFID, 2011)

The five main elements of the VFM framework are as follows (DFID, 2011):

1) **Inputs** – the resources used, in terms of finance and staff time (capital and labour).
2) **Process** – the process by which inputs are transformed into results.
3) **Outputs** – the direct deliverables of the project.
4) **Outcomes** - resulting from the outputs
5) **Impacts** - the longer-term impact of the project.

In essence, the elements represent a chain of events through time, given that these different types of results would usually, but not always, take place sequentially. The causal links between these different types of results need to be informed by evidence, however, as a sustained actual outcome or an impact in the programme area may be influenced by factors outside the programme.

The main dimensions of the VFM framework are as follows (DFID, 2011):

(a) **Economy:** Relates to the price at which inputs are purchased. For example, are DFID's agents buying inputs (e.g. consultancy services) at the appropriate quality and the right price?

(b) **Efficiency:** Relates to how well inputs are converted into a specific output, i.e. the results delivered by DFID's agents to an external party such as a partner country.

(c) **Effectiveness**: Relates to how well outputs from an intervention are converted into sustained outcomes and achievement of the ultimate desired outcome on poverty reduction. Note: In contrast to outputs, the implementer does not exercise direct control over whether actual outcomes materialise and whether they can be sustained.

(d) **Cost-effectiveness:** Relates to the cost of achieving intended project actual outcomes. This can be used to compare the cost of alternative ways of producing the same or similar outcomes.

In practice, in order to obtain value-for-money on any project it would be necessary to maximise its effectiveness, efficiency and economy (the 3 Es) as well as the strength of the links in the results chain. The issue of equity also needs to be considered to make sure that the outcomes of the project are not only sustainable but, importantly, they are targeted at the poorest and include sufficient gender targets.

4.3 Evaluation of VFM

In accordance with the ToR, a key requirement of the project is to evaluate road sections designed using the DCP-DN method in terms of the following aspects:

- cost-effectiveness
- outcome (uptake) and knowledge
- potential impact.

The outcome of this evaluation is presented below.

4.3.1 Cost-effectiveness

The cost-effectiveness of the DCP-DN method of design, as against other typical methods of design (TRH4, DCP-CBR and ORN31) may be evaluated on the basis of the following:

- Pavement cost ratios
- Total project cost ratios
- Total project cost difference/km

The outcome of the above measures of cost-effectiveness has been presented in Section 3 for both the hypothetical and in-situ designs. In terms of project cost differences/km, which are of most interest to road agencies, and based on the wide range of design scenarios (1728) considered in the hypothetical approach, the DCP-DN design method will, in the majority of the cases, provide savings in the range of USD 10,000 -20,000 per km, and in many cases more than USD20,000/km. These savings occur to a lesser extent in the higher TLCs (0.7 – 1.0 MESA) and, in some cases of this traffic range close to 1.0 MESA, other design methods, particularly ORN31, are more cost-effective than the DCP-DN design method. These figures illustrate the general cost-effectiveness of the DCP-DN methods against the other design methods.

In light of the above findings, it is noteworthy that in many African countries the continued use of gravel as a road surfacing material is unsustainable. This fact, coupled with the relatively low traffic thresholds for justifying economically the upgrading of gravel roads to a paved standard (often < 100 vpd, depending on road environment conditions (Morusuik et al, 2000)), makes such upgrading a very attractive option. Given that many countries in Africa have embarked on programmes for improving basic access in rural areas by providing paved roads, typically of the order of 100 – 150 km/annum, the benefits of adopting an appropriate pavement design method, such as the DCP-DN method, at traffic levels up to about 0.7 MESA over a 10 – 15 year design life, are substantial. For example, for the twelve African countries participating in ReCAP, over a 5-year planning horizon, and based on the extreme scenarios indicated above, the savings would be of the order of USD 60 – 180 million. When extrapolated to all 46 countries in Sub-Saharan Africa, this figure would be of the order of USD 2.7 – 18 billion depending on the extent of the upgrading programmes in these countries.

4.3.2 Outcome (uptake)

In line with one of the key aims of ReCAP, the project outcome is expected to *promote sustained increase in the evidence base for more cost effective and reliable provision of LVRs as well as to influence policy and practice in Africa and Asia.* Thus, the outcome of the project can be assessed in relation to such factors as:

(1) **Sustainability**

- a. There has been active and sustained engagement of ReCAP consultants with practitioners in all the AfCAP countries and some AsCAP countries with the aim of fostering a deeper understanding of what can be done to provide more cost-effective and sustainable LVRs. This has been achieved through a variety of measures including the following:
    - i. Seminars, workshops and meetings aimed at promoting safe and sustainable rural access in Africa and Asia through research and knowledge sharing between participating countries and the wider community.
    - ii. Establishment of project Working Groups or Steering Committees comprised of key practitioners involved in the design of LVRs. This has provided fora for discussing a wide range of issues associated with the environmentally optimised design of LVRs, including the use of appropriate, cost-effective design methods.
    - iii. Construction and long-term monitoring of a number of demonstration or trial sections to verify the soundness of the DCP-DN design method.
- b. There has been a strong contribution in kind from partner Governments in a number of countries (e.g. Ghana, Zambia) in terms of staff time and funding/co-funding of construction of trial sections, sometimes with other bi-lateral donors.
- c. A number of basic and advanced training courses in the DCP-DN method of design have been held for engineers and technicians in a number of both AfCAP (Kenya, Tanzania, Malawi, Ghana), and AsCAP countries (Nepal) where trainees from other countries were hosted. As a result of such training, there is now a cadre of trained and motivated practitioners, some 146 engineers and 64 technicians, many of whom will be in a position to mainstream the DCP-DN method of design in their organisations. Four such trained practitioners have been certified as AfCAP Level 1: Lead Trainers which qualifies them to undertake such training in their countries or abroad.

(2) **Uptake**

- a. The uptake of the DCP-DN method of design has been manifested as follows:
    - I. Partner country financing of LVRs based on the DCP-DN method in some countries including, so far, Malawi, Ghana and Zambia.
    - II. Local standards and specifications have been revised to allow the option of using the DCP-DN method in a number of countries, including Ethiopia, South Sudan, Tanzania, and Mozambique. Such revision is also on-going in a number of other countries including Malawi, Zambia, Ghana, Sierra Leone and Liberia

(3) **Quality of DCP-DN research**

- a. The quality of DCP-DN research has manifested itself as follows:
    - I. An internationally peer reviewed paper on the DCP-DN pavement design method has been published in the UK ICE Proceedings (Rolt and Pinard, 2016).
    - II. Numerous papers on the DCP-DN design method have been presented at a number of international and regional conferences (e.g. Klein and Savage, 1982; Kleyn and Van Heerden, 1987; Kleyn and Van Zyl, 1987; De Beer, 1991; Paige-Green, 2011; Paige-Green and Pinard, 2012; Pinard and Paige-Green, 2013; Pinard et al, 2015).

(4) **Knowledge of the DCP-DN method**
   a. The knowledge base for the DCP-DN method of pavement design is gradually increasing in terms of the following:
      i. The number of certified trainers who have themselves applied the method in practice in their countries. This includes, so far, countries such as Ghana, Zambia and Malawi.
      ii. Incorporation in curriculum of tertiary institutions including universities and technical colleges is currently under consideration by ReCAP.

4.3.3 Potential impact:

The longer-term potential impact of the sustained use of the DCP-DN method of pavement design or, indeed, any DCP-related method of design, for upgrading unpaved roads to a paved standard, would be a contributory factor in:

(1) **Reduced costs/increased cost-effectiveness of LVR provision**
With the increasing uptake and mainstreaming of the DCP-DN method and other DCP-related methods of pavement design, there is now significant scope for reducing costs/increasing the cost-effectiveness of LVR provision.

(2) **Optimum use of non-renewable resources**
The provision of a LVSR compared to a gravel road, will obviate the need for continual regravelling of LVRs and, in so doing, lead to optimum use non-renewable gravel resources.

(3) **Improved transport services at cheaper costs**
The reduction in vehicle operating costs experienced on a sealed, compared to a gravel, road, largely through the difference of roughness/riding quality of their surfaces, can be significant. For example, the roughness, in IRI terms, of a gravel road can range between 5 – 15 m/km compared to an old paved road (3 – 7 m/km) and a new paved road (2 – 3.5 m/km). Thus, as vehicle operating costs reduce, there is likely to be improved transport services at cheaper costs.

(4) **Increase in agricultural production and productivity** due to more reliable, all-season access to market places.

(5) **Improvements in education and health** due to communities being able to access such facilities in all seasons.

(6) **Increased resilience to climate impacts** due to the provision of more durable road surfaces**.**

(7) **Ultimately, poverty reduction** in the vicinity of the project area due to improvements in community livelihoods.

It must be stressed, however, that since most of the oldest DCP-DN designed sections have been in service for only about 6 years, and some of the others not even constructed, it is most unlikely that in such a relatively short time there would be any discernible, quantifiable impacts of any kind. Nonetheless, it may be possible to provide a qualitative indication of some of the potential impacts listed above from interviews with local communities.

Notwithstanding the above, the project could be the foundation upon which Regional Research Centres (RRCs) become involved in the VFM process throughout the design life (10 – 15 years) of the road sections. Thus, a similar data collection exercise, including maintenance costs, could be undertaken say after 5 years which would provide valuable information on the extent to which they provide VFM as discussed above.

5 Summary of Key Findings and Conclusions

5.1 Key Findings

5.1.1 Cost Evaluation

The key findings of the analyses emanating from the hypothetical designs, which have been found to be reflective of the outcome of the in-situ designs, are shown in Figures 3 to 6 In Section 3.3.11 from which general conclusions may be drawn:

(1) At design traffic loading up to about 0.7 MESA, and for a wide range of subgrade strengths and climatic zones, the DCP-DN design method will, in the majority of cases, provide pavement construction cost savings in the range of USD 10,000 -20,000 per km, and in many cases in excess of USD20,000/km when compared against the selected methods. These costs savings are reduced by about 30 to 60% for the zero-haulage scenario.

(2) The pavement construction cost savings offered by the DCP-DN method occur to a lesser extent in the higher Traffic Loading Classes (TLCs) (0.7 MESA and above) when, in some cases, other design methods, particularly ORN31, are more cost-effective in this higher traffic range.

In general terms, the difference in pavement construction costs per km for the various design methods, and the pavement construction cost efficiency of the DCP-DN design method, relative to the other design methods, decreases with higher quality subgrades and higher TLCs. Also, for the specific set of environmental conditions considered, there is no major difference in the trends between Wet and Dry-Moderate environments.

5.1.2 Value for Money

In terms of Value for Money (VFM), the DCP-DN method has been evaluated in terms of the following:

(1) ***Cost-effectiveness:*** The outcome of the various cost evaluations undertaken and summarised above illustrate the general cost-effectiveness of the DCP-DN method against the other design methods.

Given that many countries in Africa have embarked on programmes for improving basic access in rural areas by upgrading gravel roads to a paved standard, typically of the order of 100 – 150 km/annum, the potential benefits of adopting the DCP-DN method over a 5-year planning horizon, could result in cost savings of the order of USD60 – 180 million, depending on the extent of the upgrading programme and the road environment conditions. When extrapolated to all 46 Sub-Saharan countries, this figure is estimated at USD 2.7 – 18 billion.

(2) ***Outcome (uptake) and knowledge***: This has been assessed in terms of the following:

a. *Sustainability*: This has been demonstrated in terms of the following typical examples:

i. Seminars, workshops and meetings aimed at knowledge sharing between participating ReCAP countries and their wider community of practitioners.

ii. Establishment of Working Groups or Steering Committees with the objective of discussing intensively issues associated with the environmentally optimised design of LVRs.

iii. Construction and long-term monitoring of demonstrating or trial sections designed on the basis of the DCP-DN method.

iv. Contributions in kind from partner Governments in terms of staff time and funding/co-funding with bi-lateral partners

v. The holding of basic and advanced training courses in the DCP-DN method of design for engineers and technicians that have led to the certification of four AfCAP Level 1

Trainers which qualifies them to undertake such training nationally or internationally. Once such trainer has already been involved in an international DCP training programme.

(b) *Uptake:* This has been manifested as follows:

  i. ReCAP country partner financing of the DCP-DN design method in three countries so far.
  ii. Inclusion of DCP-DN requirements in local standards and specifications of at least four countries so far, and on-going revisions in at least another five countries.

(c) *Quality of DCP-DN research:* This has been manifested as follows:

  I. Production of at least one internationally peer-reviewed paper on the DCP-DN method of design in the research proceedings of a major civil engineering institution I the UK
  ii. Production and presentation of at least 7 peer reviewed papers on the DCP-DN method of design in a number of regional and international conferences (Kleyn and Savage, 1982; Kleyn and Van Heerden, 1983; Kleyn and Van Zyl, 1987; Paige-Green, 2011; Paige-Green and Pinard, 2012; Pinard and Paige-Green, 2013; Pinard et al, 2015).

(d) *Knowledge of the DCP-DN method.* This has been manifested as follows:

  i. An increase in the knowledge base for the DCP-DN method of pavement design which is gradually increasing in terms of the following:
    a. The number of certified trainers who have themselves applied the method in practice in at least three countries.
    b. Incorporation in at least one international course in Rural Roads for Development held at the University of Birmingham, UK.
    c. Involvement of university lecturers as trainee trainers in the use of the DCP-DN method for LVR pavement design.

(3) ***Potential impact:*** Although it may be too soon to start quantifying the impact of introducing the DCP-DN method of design for the more recently constructed trial sections, or of adopting any DCP-related method of design for future LVRs, such impacts are likely to be a factor within the causal package leading to:

  a. Reduced cost/increased cost-effectiveness of LVR provision.
  b. Optimum use of non-renewable gravel resources.
  c. Improved transport services at cheaper costs.
  d. Increase in agricultural production and productivity due to more reliable, all-season access to market places.
  e. Improvements in education and health due to communities being able to access such facilities in all seasons.
  f. Increased resilience to climate impacts due to more durable paved road surfaces.
  g. Ultimately, poverty reduction in the vicinity of the project due to improvements in community livelihoods.

In summary, the use of the DCP-DN method and, indeed other methods such as ORN31 in some road environment situations, is expected to provide Value for Money in terms of the following:

a. Cost-effectiveness.
b. Outcome (uptake) and knowledge.
c. Potential impact.

5.2 Main Conclusions

The main conclusion to be drawn from the very wide range of design evaluations is that, in general, the DCP-DN method is the most cost-effective design option at relatively low TLCs, up to about 0.7 MESA and across all subgrade strengths. However, at TLCs above 0.7 MESA the method gradually becomes less cost effective than the other methods, particularly ORN31, which become more cost-effective in many situations.

It is also interesting to note that ORN31 has been shown to be generally more cost-effective than its successor for LVR design, the DCP-CBR method, in all design environments. This may be partly explained by two reasons:

(1) ORN31, together with the DCP-DN method, and in contrast to the DCP-CBR and TRH4 design methods, allows for the use of unsoaked subgrades which offer scope for using relatively thinner/less costly pavement structures.

(2) The adopted soaked/unsoaked subgrade CBR ratio for the DCP-CBR method appears to be very conservative compared to that adopted in the DCP-DN and ORN31 methods.

One of the major benefits of the hypothetical evaluation spreadsheets is that they can be used by practitioners to determine what are the likely costs of their designs in a particular set of road environment conditions, and which is the most appropriate design method to use. The spreadsheets also offer the potential for being developed as an application tool for undertaking LVR design based on a set of input parameters.

5.3 Way Forward

In terms of the way forward, and based on the many lessons learnt during the course of undertaking this project, the following recommendations are made:

(1) A practitioner's workshop should be held to discuss and disseminate the findings of this report.

(2) As part of the on-going ReCAP project on Long Term Pavement Performance (LTPP) monitoring of trial sections in a number of partner countries, measurement of in-situ moisture in the pavement layers and subgrade, and across the horizontal profile of the sections, should be given high priority in order to validate the assumptions made on this parameter in all the design methods.

(3) In order to embed in practice the potential benefits to be derived from the use of the DCP-DN method, a generic guideline on the Design of Low Volume Roads should be produced so as to provide practitioners with another choice of design method for their consideration.

(4) The Regional Research Centres should undertake a similar data collection exercise to the one initiated under this project, in say 5 years' time, so as to consolidate on the preliminary results of the VFM exercise initiated under this project. This should also include performance data e.g. road roughness measurements to incorporate vehicle operating costs/benefits in the LCC analysis for comparison of design method cost-effectiveness.

(5) Consideration should be given to improving, and possible extending the spreadsheets developed under this project as an application tool for undertaking LVR design based on any set of input parameters to determine what are the likely costs of their designs in a particular set of road environment conditions, and which is the most appropriate design method to use.

(6) Consider the following topics for further research to enhance the efficacy and applicability of the DCP-DN design method

    a. Determine the precision limits of the DCP-DN measurement as against the CBR measurement as adopted by other LVR design methods.

b. Compare the designs produced by the DCP-DN and other design approaches (DCP-CBR, TRH4 and ORN31) with an analytical approach.

c. Use suitably calibrated road investment appraisal models such as HDM-4 or the World Bank's Roads Economic Development Model (RED) to appraise robustly the LCCs of the DCP-DN and other design approaches.

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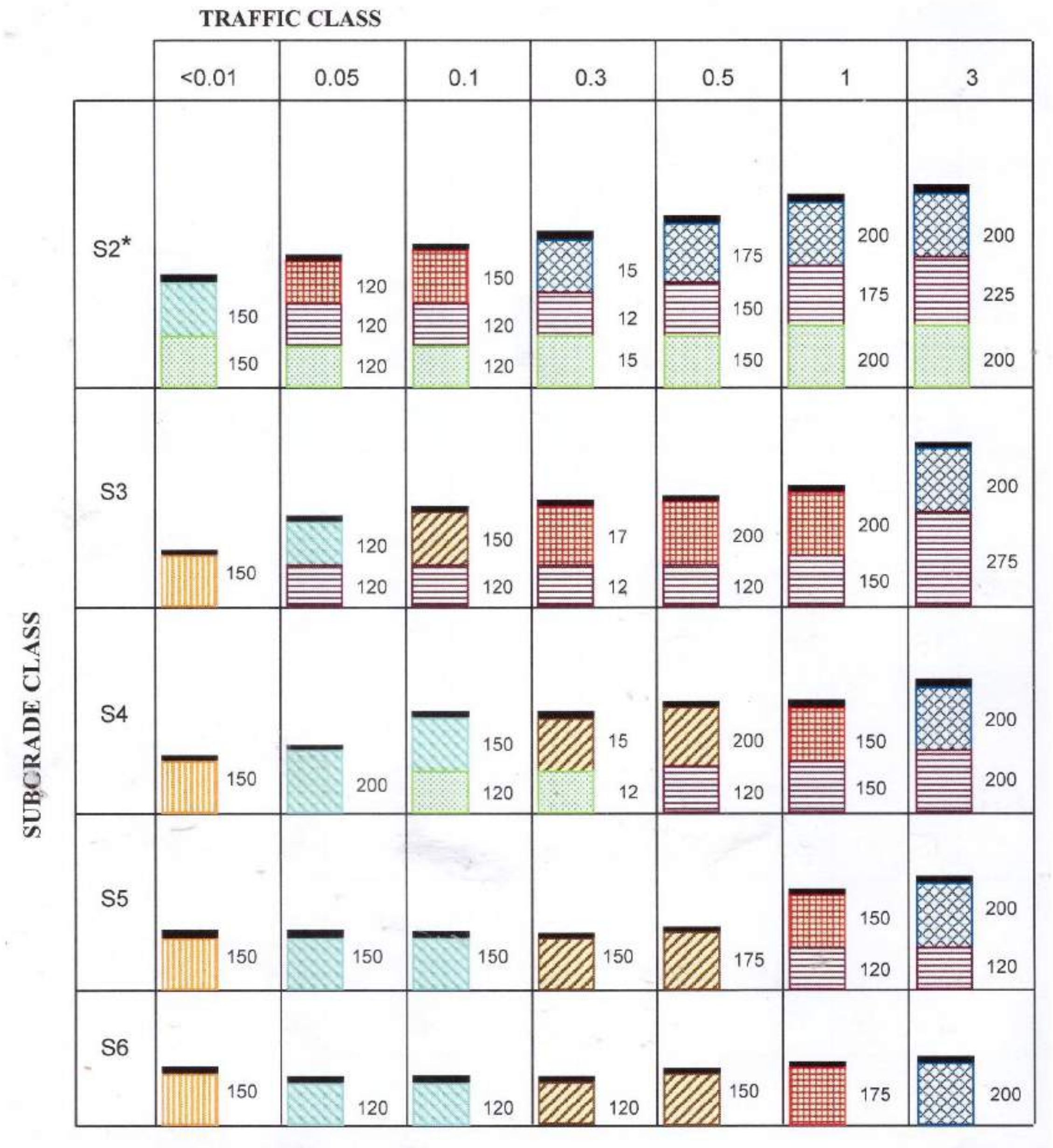
Annexes

Annex A – DCP-DN Structural Design Catalogue

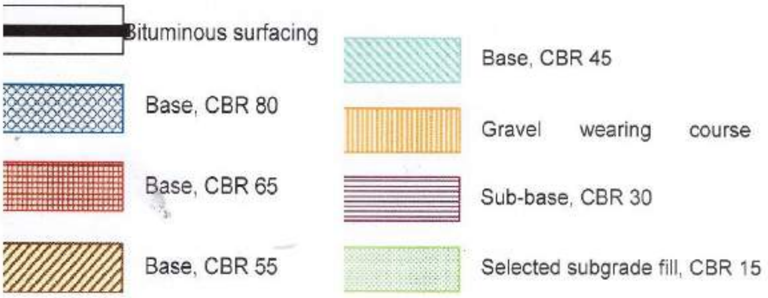
Traffic Class **E80 x 10^6**	**0.01** **0.003 – 0.01**	**0.03** **0.01 – 0.03**	**0.1** **0.03 – 0.10**	**0.3** **0.10 – 0.30**	**0.7** **0.30 – 0.70**	**1.0** **0.70 – 1.0**
0- 150mm Base ≥ 98% Mod. AASHTO	DN ≤ 8	DN ≤ 5.9	DN ≤ 4	DN ≤ 3.2	DN ≤ 2.6	DN ≤ 2.5
150-300 mm Subbase ≥ 95% Mod. AASHTO	DN ≤ 19	DN ≤ 14	DN ≤ 9	DN ≤ 6	DN ≤ 4.6	DN ≤ 4.0
300-450 mm subgrade ≥ 95% Mod. AASHTO	DN ≤ 33	DN ≤ 25	DN ≤ 19	DN ≤ 12	DN ≤ 8	DN ≤ 6
450-600 mm In-situ material	DN ≤ 40	DN ≤ 33	DN ≤ 25	DN ≤ 19	DN ≤ 14	DN ≤ 13
600-800 mm In-situ material	DN ≤ 50	DN ≤ 40	DN ≤ 39	DN ≤ 25	DN ≤ 24	DN ≤ 23
DSN 800	≥ 39	≥ 52	≥ 73	≥ 100	≥ 128	≥ 143

Annex B – DCP-CBR Structural Design Catalogue (N > 4)



Note: * Non-expansive subgrade

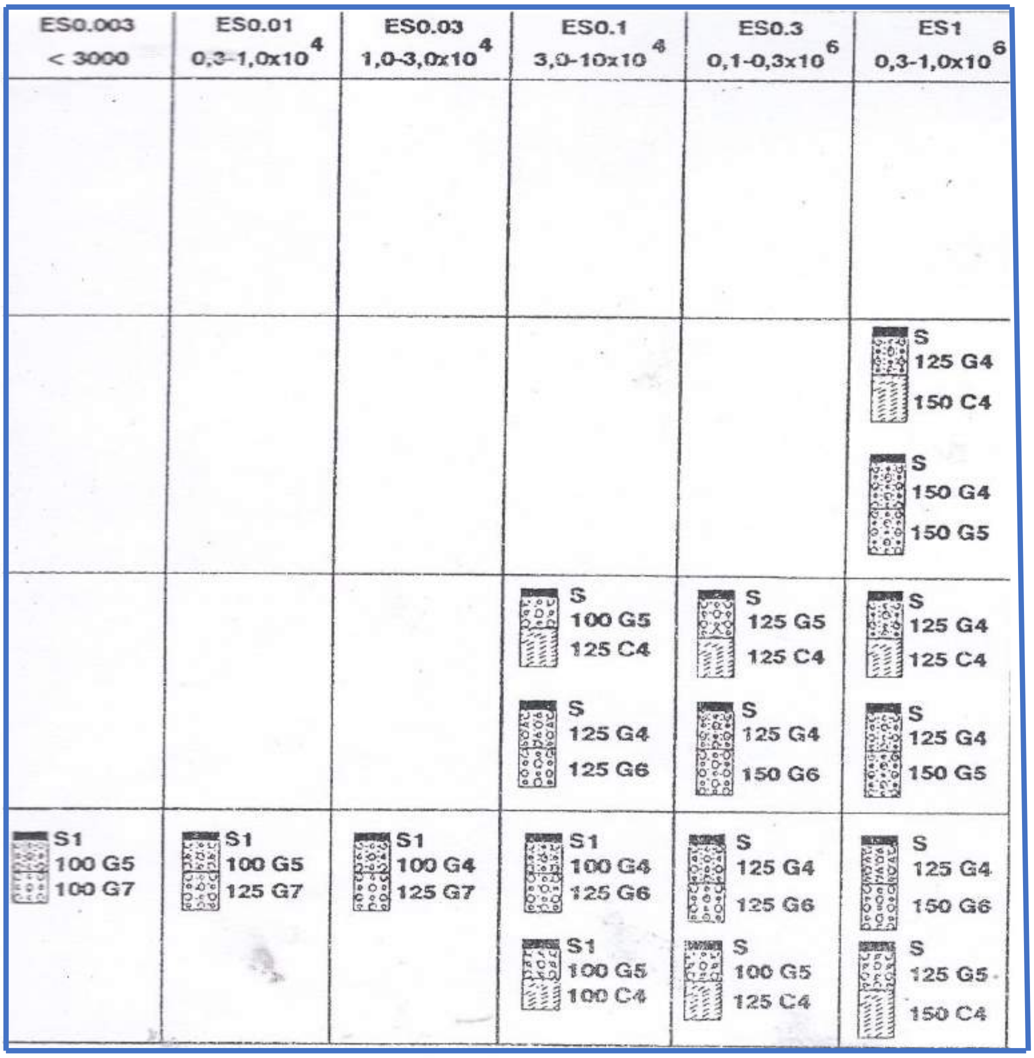
Key



Subgrade strength classes (CBR%)

S2 = 3-4
S3 = 5 – 7
S4 = 8 – 14
S5 = 15 – 29
S6 = 30^{+}

Annex C – TRH4 Structural Design Catalogue (Dry-Moderate Region)

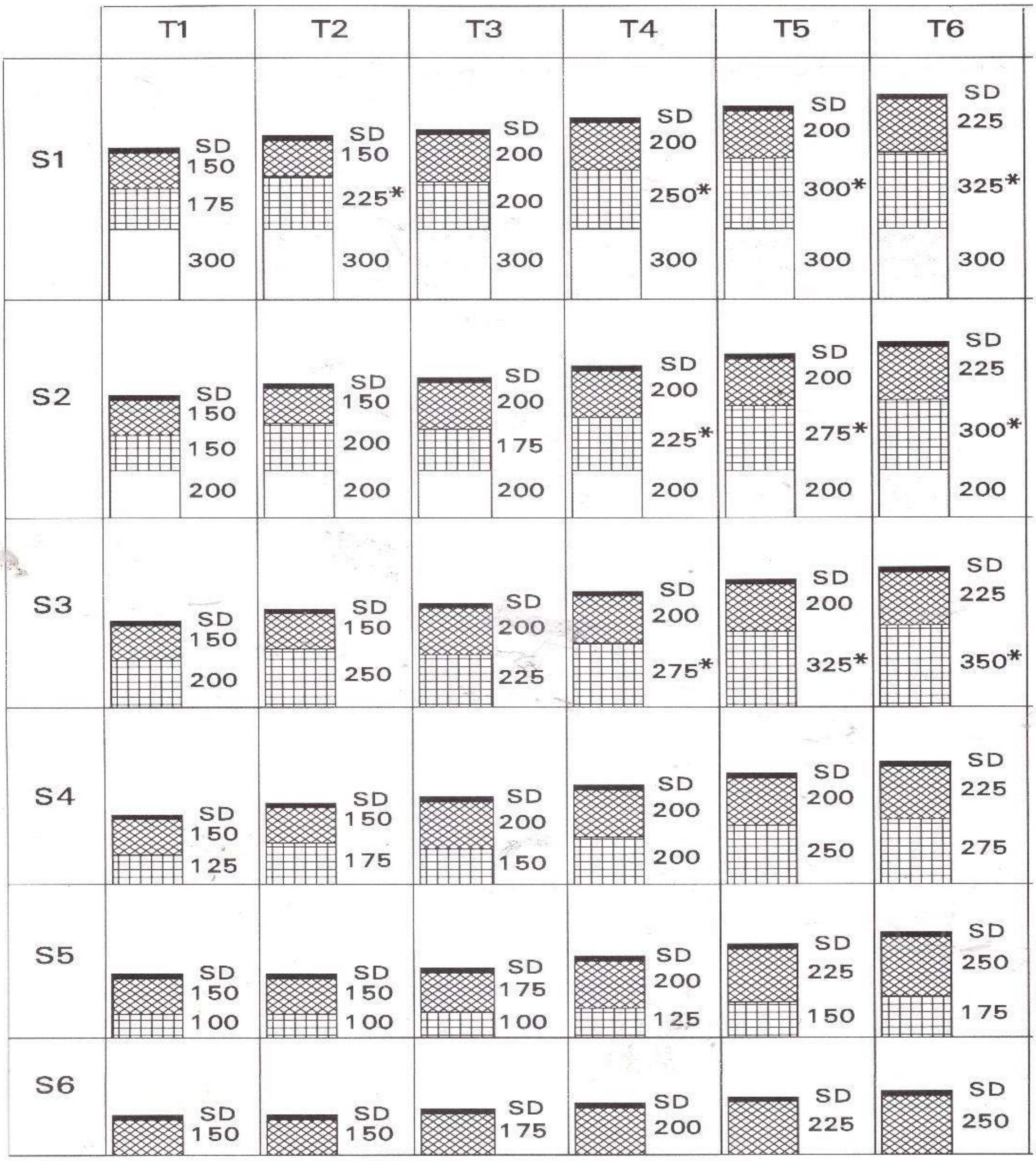


ES0.003 < 3000	ES0.01 0,3-1,0x10^4	ES0.03 1,0-3,0x10^4	ES0.1 3,0-10x10^4	ES0.3 0,1-0,3x10^6	ES1 0,3-1,0x10^6
					S 125 G4 150 C4 S 150 G4 150 G5
			S 100 G5 125 C4 S 125 G4 125 G6	S 125 G5 125 C4 S 125 G4 150 G6	S 125 G4 125 C4 S 125 G4 150 G5
S1 100 G5 100 G7	S1 100 G5 125 G7	S1 100 G4 125 G7	S1 100 G4 125 G6 S1 100 G5 100 C4	S 125 G4 125 G6 S 100 G5 125 C4	S 125 G4 150 G6 S 125 G5 150 C4

SYMBOL	CODE	MATERIAL	ABBREVIATED SPECIFICATIONS
	G4	Crushed or natural gravel	Minimum CBR = 80 % @ 98 % Mod. AASHTO; Maximum size 37,5 mm; 98 - 100 % Mod. AASHTO; PI < 6; Maximum Swell 0,2 % @ 100 % Mod. AASHTO. For calcrete PI ≤ 8
	G5	Natural gravel	Minimum CBR = 45 % @ 95 % Mod. AASHTO; Maximum size 63 mm or 2/3 of layer thickness; Density as per prescribed layer usage; PI < 10; Maximum swell 0,5 % @ 100 % Mod. AASHTO *
	G6	Natural gravel	Minimum CBR = 25 % @ 95 % Mod. AASHTO; Maximum size 63 mm or 2/3 of layer thickness; Density as per prescribed layer usage; PI < 12; Maximum swell 1,0 % @ 100 % Mod. AASHTO *
	G7	Gravel / Soil	Minimum CBR = 15 % @ 93 % Mod. AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; PI < 12 or 3GM** + 10; Maximum swell 1,5 % @ 100 % Mod. AASHTO ***
	G8	Gravel / Soil	Minimum CBR = 10 % @ 93 % Mod. AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; PI < 12 or 3GM** + 10; Maximum swell 1,5 % @ 100 % Mod. AASHTO ***
	G9	Gravel / Soil	Minimum CBR = 7 % @ 93 % Mod. AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; PI < 12 or 3GM** + 10; Maximum swell 1,5 % @ 100 % Mod. AASHTO ***
	G10	Gravel / Soil	Minimum CBR = 3 % @ 93 % Mod. AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; or 90% Mod. AASHTO

Annex D – ORN31 Design catalogue

Chart 1 – Granular Road base/Surface Dressing



	T1	T2	T3	T4	T5	T6
S1	SD 150 175 300	SD 150 225* 300	SD 200 200 300	SD 200 250* 300	SD 200 300* 300	SD 225 325* 300
S2	SD 150 150 200	SD 150 200 200	SD 200 175 200	SD 200 225* 200	SD 200 275* 200	SD 225 300* 200
S3	SD 150 200	SD 150 250	SD 200 225	SD 200 275*	SD 200 325*	SD 225 350*
S4	SD 150 125	SD 150 175	SD 200 150	SD 200 200	SD 200 250	SD 225 275
S5	SD 150 100	SD 150 100	SD 175 100	SD 200 125	SD 225 150	SD 250 175
S6	SD 150	SD 150	SD 175	SD 200	SD 225	SD 250

Annex E - Equilibrium to Optimum moisture content ratios (Emery, 1985)

Subgrade			**Subbase**			**Base**		
Mean	SD	N	Mean	SD	N	Mean	SD	n
Arid								
0.71	0.34	131	0.70	0.26	19	0.53	0.24	26
Cape (winter rain)								
0.75	0.45	81	0.78	0.28	17	0.63	0.16	16
Cape (all year rain)								
0.98	0.31	98	0.83	0.28	20	0.57	0.17	19
Transvaal (Im < 0)								
0.94	0.29	894						
Transvaal (Im > 0)								
0.96	0.29	178						
Natal (Im > 0)								
1.05	0.34	52						
Weighted Mean								
0.92			**0.75**			**0.58**		

Annex F – Road section details and outcome of visual condition assessments

D379-Wamwangi-Karatu road, Kenya:

Photo: June 2018

(1) Outline details

1. Climate: Rainfall 1000 mm/year
2. Design life: 15 years
3. Design traffic loading class: TLC 01 (0.03 – 0.1 MESA)
4. Pavement structure
   - i. 15 mm Cold Mix Asphalt surfacing
   - ii. 150 mm base: DN value ≤ 4 (equivalent CBR ≥ 70 atOMC, CBR ≥ 45 soaked)
   - iii. 150 mm subbase: DN value ≤ 9 (equivalent CBR ≥ 25 at OMC
   - iv. 150 mm subgrade: DN value ≤ 19 (equivalent CBR ≥ 10 at OMC

(2) Construction

1. **Date of construction:** 2012
2. **Construction cost:** USD154,000/km (2012) (USD 1.00 = KES 84.00)

(3) **Maintenance:** Only roadside and drain maintenance has been carried out on the road since completion. The grass in the drains has been cut and some, but insufficient, desilting has occasionally been carried out.

(4) **Overall condition:** Rated as good. Recent structural assessments indicated rutting values of < 10 mm (July 2017) and roughness values (IRI) of 3.7 m/km. In-situ moisture contents measured at the end of the 2018 rainy season indicate that the values in the OWT are all well below OMC in all the layers of the pavement.

(5) **Summary**: Despite lack of attention to maintenance, the road has performed well so far, after 6 years of a 15-year design life. However, continued lack of adequate routine maintenance is likely to jeopardise the condition/performance of the road. Moreover, periodic maintenance, in the form of a surfacing reseal, is likely to be required in the near future.

The total construction cost/km of USD 154,000 is low compared to costs for comparable projects with conventional design under Roads 2000. With economies of full scale construction of an entire road using the same design and construction method, the costs/km could be reduced.

Lawate - Kibongoto road, Tanzania


Photo: June 2018

(1) Outline details

1. Climate: Wet - Rainfall > 1000 mm/year
2. Design life: 15 years
3. Design traffic loading class: TLC 0.03 (0.01 – 0.03 MESA)
4. Pavement structure
    i. 19/9.5 mm Double Surface Dressing
    ii. 150 mm base: DN value ≤ 5.9 (equivalent CBR ≥ 25 atOMC)
    iii. 150 mm subbase: DN value ≤ 14 (equivalent CBR ≥ 15 at OMC)
    iv. 150 mm subgrade: DN value ≤ 25 (equivalent CBR ≥ 7 at OMC)

(2) Construction

1. **Date of construction:** September, 2012.
2. **Construction cost**: USD 45,125/km/4m wide carriageway. Construction entailed scarification and re-compaction of the existing gravel wearing course and importation of a base layer only. The equivalent cost based on the traditional design approach stipulated in the Tanzania Pavement and Materials Design manual was USD 61,125/km/4 m wide carriageway.

(3) **Maintenance:** Practically no maintenance has been carried out since construction of the road. This has resulted in significant vegetation growth in the drains and adjacent to the paved carriageway.

(4) **Overall condition**: Rated good. Structural assessments of the road indicated rutting values of < 8 mm (April 2014) and roughness values (IRI) of 3.7 m/km (April, 2014.

(5). **Summary:** Despite lack of attention to maintenance, the road has performed well so far, after almost 6 years of a 15-year design life. However, continued lack of adequate routine maintenance is likely to jeopardise the condition/performance of the road. Moreover, periodic maintenance, in the form of a surfacing reseal, is likely to be required in the near future.

The average cost saving/km based on the DCP-DN method was of the order of USD 16,000/km/ 4m wide carriageway.

Danger Point road 4019, Western Cape, South Africa

Photo: June 2018

(1) Outline details

1. Climate: Dry-Moderate: Rainfall < 1000 mm/year
2. Design life: 20 years
3. Design traffic loading class: TLC 0.3 (0.10- 0.30 MESA)
4. Pavement structure
    - i. 10 mm Single Surface Dressing + Sand Seal
    - ii. 150 mm base: DN value ≤ 3.2 (equivalent CBR ≥ 90 at 0.75 OMC)
    - iii. 150 mm subbase: DN value ≤ 6 (equivalent CBR ≥ 45 at 0.75 OMC
    - iv. 150 mm subgrade: DN value ≤ 12 (equivalent CBR ≥ 12 at 0.75 OMC

(2) Construction

1. **Date of construction:** May 2003
2. **Construction cost**: Rand 241,530 (USD 32,250)/km/5m wide carriageway. Construction entailed scarification and re-compaction of the existing gravel wearing course (soaked CBR 45) and then sealing the surface.

(3) **Maintenance:** Adequate routine maintenance has been carried out since construction of the road. Periodic maintenance included a 7 mm Single Surface Dressing in 2014.

(4) **Overall condition**: fair – Good based on a Visual Condition Survey carried out in 2015.

(5). **Summary:** With adequate routine and periodic maintenance having being carried out since construction, the road has performed well after 15 years of its 20-year design life. It is expected to easily be able to carry the design traffic 0.3 MESA without any significant failures in service.

Nelshoogte (R38 to Nelshoogte Sawmill)

(1) Outline details

1. Climate: Wet - Rainfall > 1000 mm/year
2. Design life: 20 years
3. Traffic loading class: 0.7 (0.30 – 0.70 MESA)
3. Pavement structure
    i. 19/9.5 mm Double Surface Dressing
    ii. 150 mm base: DN value ≤ 2.6 (equivalent CBR ≥ 120 atOMC)
    iii. 150 mm subbase: DN value ≤ 4.6 (equivalent CBR ≥ 60 at OMC
    iv. 150 mm subgrade: DN value ≤ 8 (equivalent CBR ≥ 20 at OMC

(2) **Construction**

1. Date of construction: 1990
2. Construction cost: Rand 60,000/km (USD 22,960.00). Construction entailed scarification and re-compaction of the existing gravel wearing course (soaked CBR 45) and importation of base layer as above.

(3) **Maintenance:** Practically no maintenance has been carried out since construction of the road. This has resulted in significant vegetation growth in the drains and adjacent to the paved carriageway.

(4) **Overall condition**: Good

(5). **Summary**: After more than 27 years in service, the road has performed remarkably well. It has carried an estimated 0.8 – 1.0 MESA which is in excess of its design traffic loading of 0.7 MESA and has served well in excess of its design life of 20 years.

Annex G – Cost Comparison of LVR design methods

1. Introduction

A total of 1728 situations have been evaluated using the four different design methods and varying:

- 3 Traffic classes
- 4 In-situ subgrade conditions
- 2 climatic conditions
- 6 Material types available
- 3 haul distances

The purpose of this Appendix is to provide an example of the process followed to determine project costs per km (when designed using the different methods), cost ratios and savings when using the DCP-DN method.

2. Situation

An example is provided of cost calculations for the different design methods in the following situation:

- Wet environment
- In-situ material: CBR 3
- Traffic class: 0.3 MESA
- Haul distance: Medium (20km)
- Available material within free haul distance: CBR15

3. DCP-DN

For 0.3 MESA, the required pavement structure in terms of DN and field CBR are displayed in Table 1.

Table 26 DCP-DN required pavement structure (DN values)

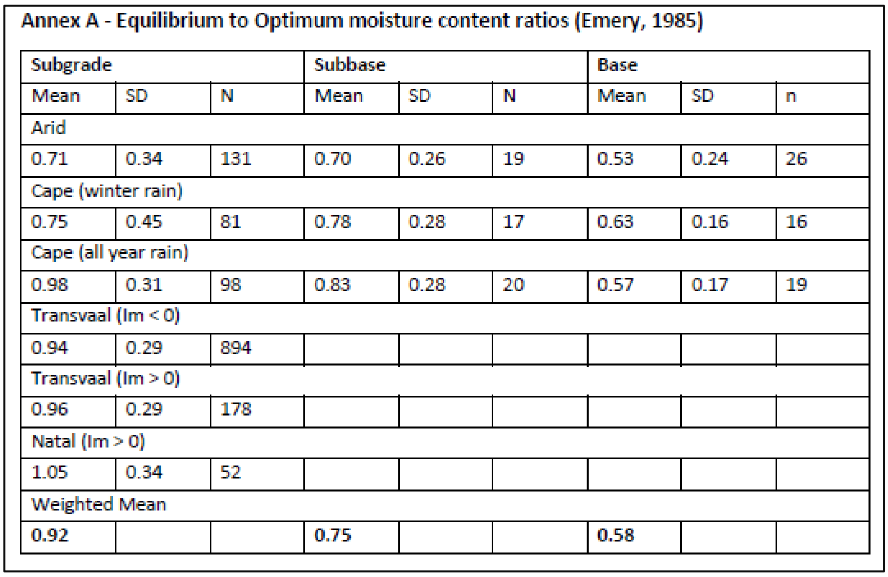
Traffic Class	**0.3**
MESA range	**0.1-0.3**
0- 150mm Base	DN ≤ 3.2
≥ 98% Mod. AASHTO	
150-300 mm Sub-base	DN ≤ 6
≥ 95% Mod. AASHTO	
300-450 mm Subgrade	DN ≤ 12
≥ 95% Mod. AASHTO	
450-600 mm	DN ≤ 19
In situ material	
600-800 mm	DN ≤ 25
In situ material	
DSN $_{800}$	≥ 100

Table 27 DCP-DN required pavement structure (Field CBR values)

	Insitu CBR		
Traffic Class	0.1	0.3	1
MESA range	0.03-0.10	0.1-0.3	0.7-1.0
150 Base	70	94	128
150 Subbase	25	42	70
150 Selected	10	17	42
150 In-situ	7	10	16

For purposes of cost calculation and comparison with other design methods, the required material for each layer in terms of soaked CBR is determined after estimating the moisture content under which the layer will operate.

From Emery, 1985, the base will operate at approximately 0.63 of OMC and the subbase, with adequate drainage at close to 0.75 of OMC.



Annex A - Equilibrium to Optimum moisture content ratios (Emery, 1985)

Subgrade			Subbase			Base		
Mean	SD	N	Mean	SD	N	Mean	SD	n
Arid								
0.71	0.34	131	0.70	0.26	19	0.53	0.24	26
Cape (winter rain)								
0.75	0.45	81	0.78	0.28	17	0.63	0.16	16
Cape (all year rain)								
0.98	0.31	98	0.83	0.28	20	0.57	0.17	19
Transvaal (Im < 0)								
0.94	0.29	894						
Transvaal (Im > 0)								
0.96	0.29	178						
Natal (Im > 0)								
1.05	0.34	52						
Weighted Mean								
0.92			**0.75**			**0.58**		

If a slightly conservative approach is adopted, it could be assumed that both the base and subbase will operate at approximately 0.75 of OMC. The subgrade varies between 0.75 of OMC and OMC, which relates to the "Dry condition" in Emery's table.

Converting the required field CBR at 0.75 OMC to the estimated soaked CBR values, using Emery's conversion table, results in the pavement structure (soaked CBR) as shown in **Error! Reference source not found.**.

Table 28 Required pavement structure in terms of soaked CBR (Based on Emery)

DCP-DN (Wet)					
Moisture Class	**% OMC**	**Layer**	**Required Soaked CBR**		
			0.1	**0.3**	**1**
Moderate	0.75	150 Base	150 G13	150 G24	150 G47
Moderate	0.75	150 Subbase		150 G5	150 G13
Dry		150 Selected			150 G10

Using the Paige-Green and Lea conversion table (Paige-Green et al, 1999) results in a more conservative (stronger) pavement structure, as shown in Table 29.

Table 29 Required pavement structure in terms of soaked CBR (Based on Paige-Green)

DCP-DN (Wet)					
Moisture Class	**% OMC**	**Layer**	**Required Soaked CBR**		
			0.1	**0.3**	**1**
Moderate	0.75	150 Base	150 G15	150 G31	150 G60
Moderate	0.75	150 Subbase		150 G5	150 G15
Dry		150 Selected			150 G12

Taking an even more conservative approach and assuming that both the base and subbase layers will operate at OMC results in much stronger pavement structures as shown in Table 30.

Table 30 Required pavement structure if base and subbase operate at OMC

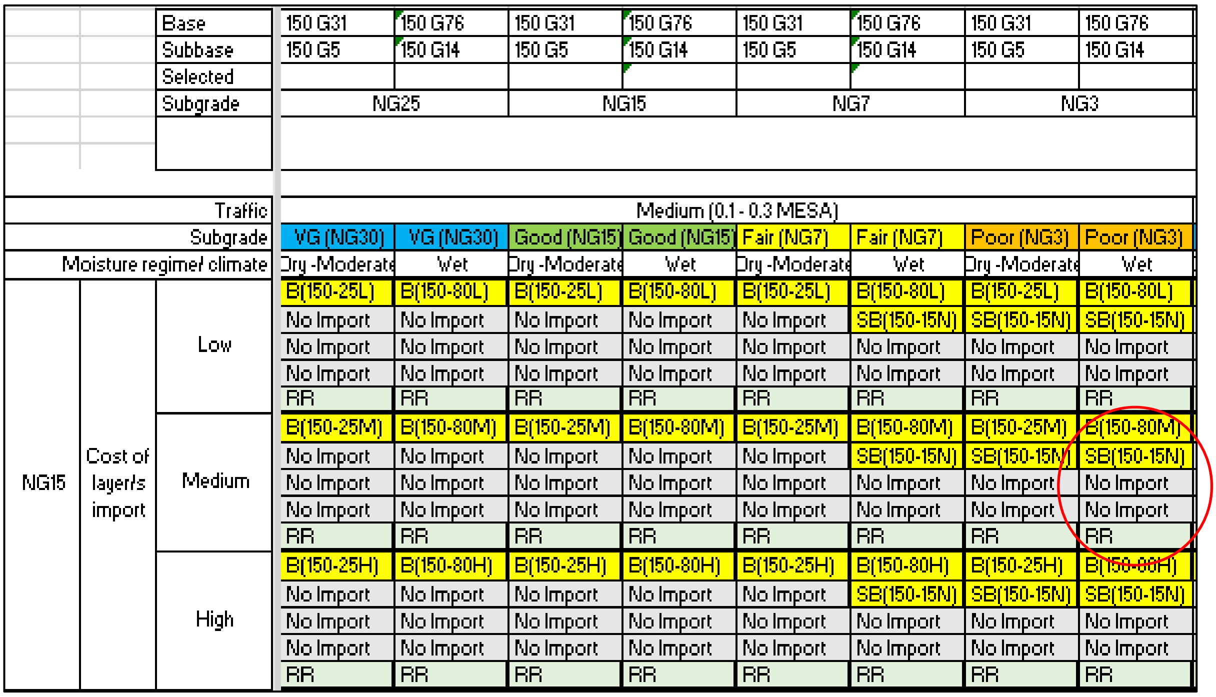
DCP-DN (Wet)					
Moisture	**%**		**Required Soaked CBR**		
Class	**OMC**	**Layer**	**0.1**	**0.3**	**1**
Damp	1	150 Base	150 G47	150 G76	150 G123
Damp	1	150 Subbase	150 G5	150 G14	150 G47
Wet		150 Selected			150 G12

In this particular case, for 0.3 MESA and the existing subgrade material being CBR=3, two layers must be imported namely:

a) 150mm subbase layer of minimum CBR=14. Available within free-haul distance is a material with soaked CBR=15

b) 150mm base layer of minimum CBR=76. Medium haul distance of material with soaked CBR of 80 selected

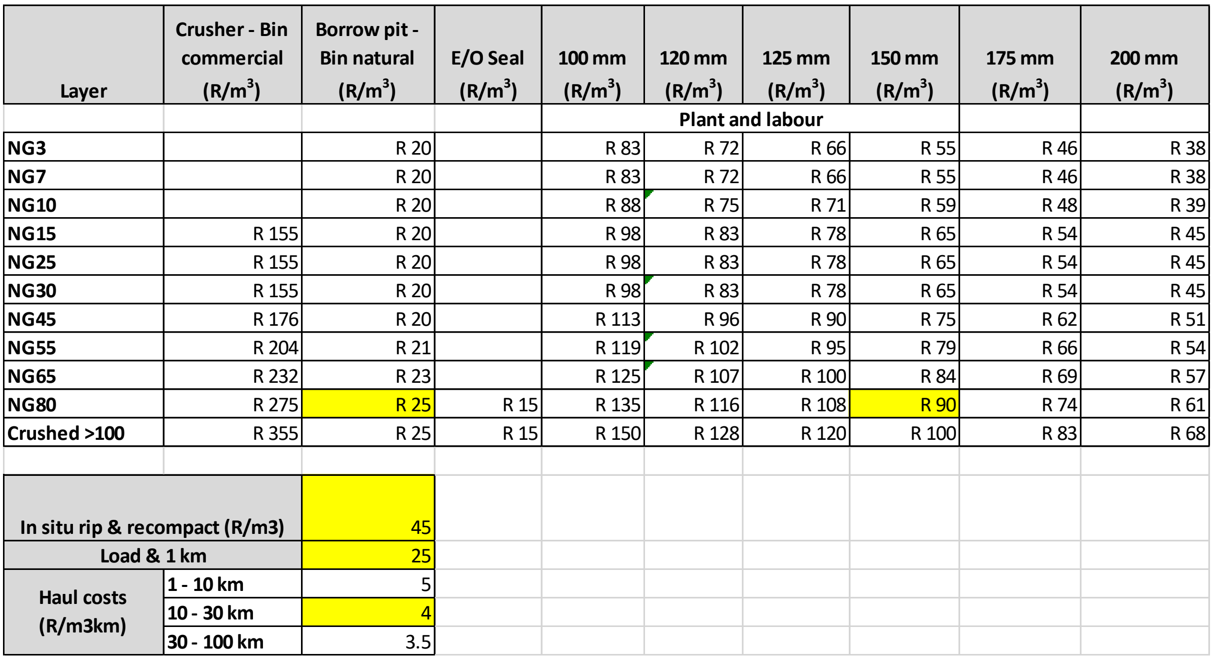
Table 31 Required pavement structures for a range of in-situ subgrades



		Base	150 G31	150 G76	150 G31	150 G76	150 G31	150 G76	150 G31	150 G76
		Subbase	150 G5	150 G14	150 G5	150 G14	150 G5	150 G14	150 G5	150 G14
		Selected								
		Subgrade	NG25		NG15		NG7		NG3	
		Traffic	Medium (0.1 - 0.3 MESA)							
		Subgrade	VG (NG30)	VG (NG30)	Good (NG15)	Good (NG15)	Fair (NG7)	Fair (NG7)	Poor (NG3)	Poor (NG3)
		Moisture regime/ climate	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
NG15	Cost of layer/s import	Low	B(150-25L)	B(150-80L)	B(150-25L)	B(150-80L)	B(150-25L)	B(150-80L)	B(150-25L)	B(150-80L)
			No Import	No Import	No Import	No Import	No Import	SB(150-15N)	SB(150-15N)	SB(150-15N)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR
		Medium	B(150-25M)	B(150-80M)	B(150-25M)	B(150-80M)	B(150-25M)	B(150-80M)	B(150-25M)	B(150-80M)
			No Import	No Import	No Import	No Import	No Import	SB(150-15N)	SB(150-15N)	SB(150-15N)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR
		High	B(150-25H)	B(150-80H)	B(150-25H)	B(150-80H)	B(150-25H)	B(150-80H)	B(150-25H)	B(150-80H)
			No Import	No Import	No Import	No Import	No Import	SB(150-15N)	SB(150-15N)	SB(150-15N)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR

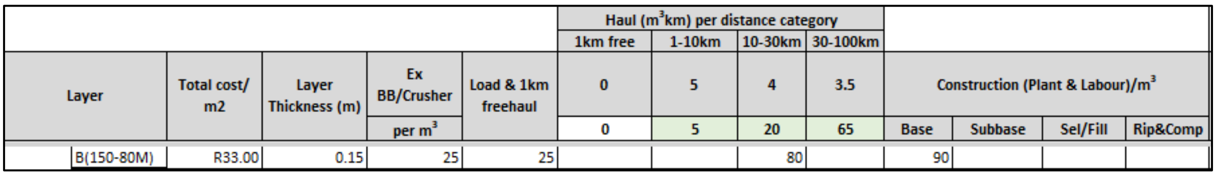
The costs per layer, incorporating material (ex borrow pit), load and 1km free haul, haul costs (20km in this case) and processing for each layer are calculated. Note: the cost values are in South African Rand and only converted to USD for final reporting.

Table 32 Material, haul and processing costs (Rand)



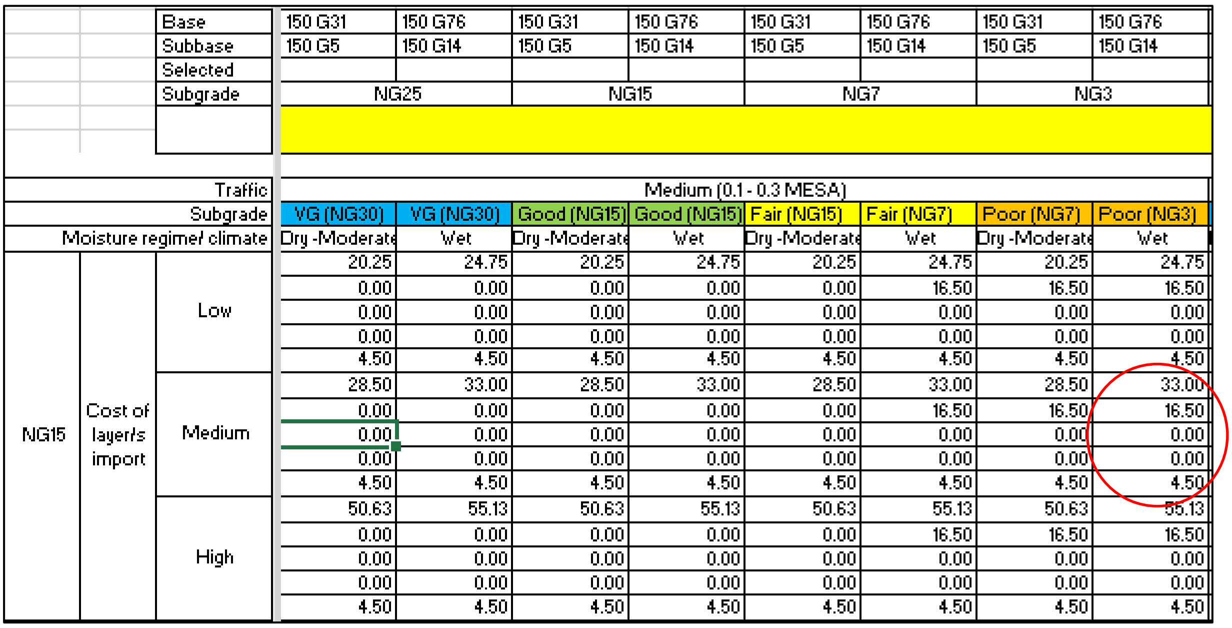
Layer	Crusher - Bin commercial (R/m³)	Borrow pit - Bin natural (R/m³)	E/O Seal (R/m³)	100 mm (R/m³)	120 mm (R/m³)	125 mm (R/m³)	150 mm (R/m³)	175 mm (R/m³)	200 mm (R/m³)
				Plant and labour					
NG3		R 20		R 83	R 72	R 66	R 55	R 46	R 38
NG7		R 20		R 83	R 72	R 66	R 55	R 46	R 38
NG10		R 20		R 88	R 75	R 71	R 59	R 48	R 39
NG15	R 155	R 20		R 98	R 83	R 78	R 65	R 54	R 45
NG25	R 155	R 20		R 98	R 83	R 78	R 65	R 54	R 45
NG30	R 155	R 20		R 98	R 83	R 78	R 65	R 54	R 45
NG45	R 176	R 20		R 113	R 96	R 90	R 75	R 62	R 51
NG55	R 204	R 21		R 119	R 102	R 95	R 79	R 66	R 54
NG65	R 232	R 23		R 125	R 107	R 100	R 84	R 69	R 57
NG80	R 275	R 25	R 15	R 135	R 116	R 108	R 90	R 74	R 61
Crushed >100	R 355	R 25	R 15	R 150	R 128	R 120	R 100	R 83	R 68
In situ rip & recompact (R/m3)		45							
Load & 1 km		25							
Haul costs (R/m3km)	1 - 10 km	5							
	10 - 30 km	4							
	30 - 100 km	3.5							

Table 33 Layer cost for a 150mm layer (soaked CBR=45)



					Haul (m^3km) per distance category							
					1km free	1-10km	10-30km	30-100km				
Layer	Total cost/ m2	Layer Thickness (m)	Ex BB/Crusher	Load & 1km freehaul	0	5	4	3.5	Construction (Plant & Labour)/m³			
			per m³		0	5	20	65	Base	Subbase	Sel/Fill	Rip&Comp
B(150-80M)	R33.00	0.15	25	25			80		90			

Table 34 Costs of different layers in the required pavement structure (DCP-DN)

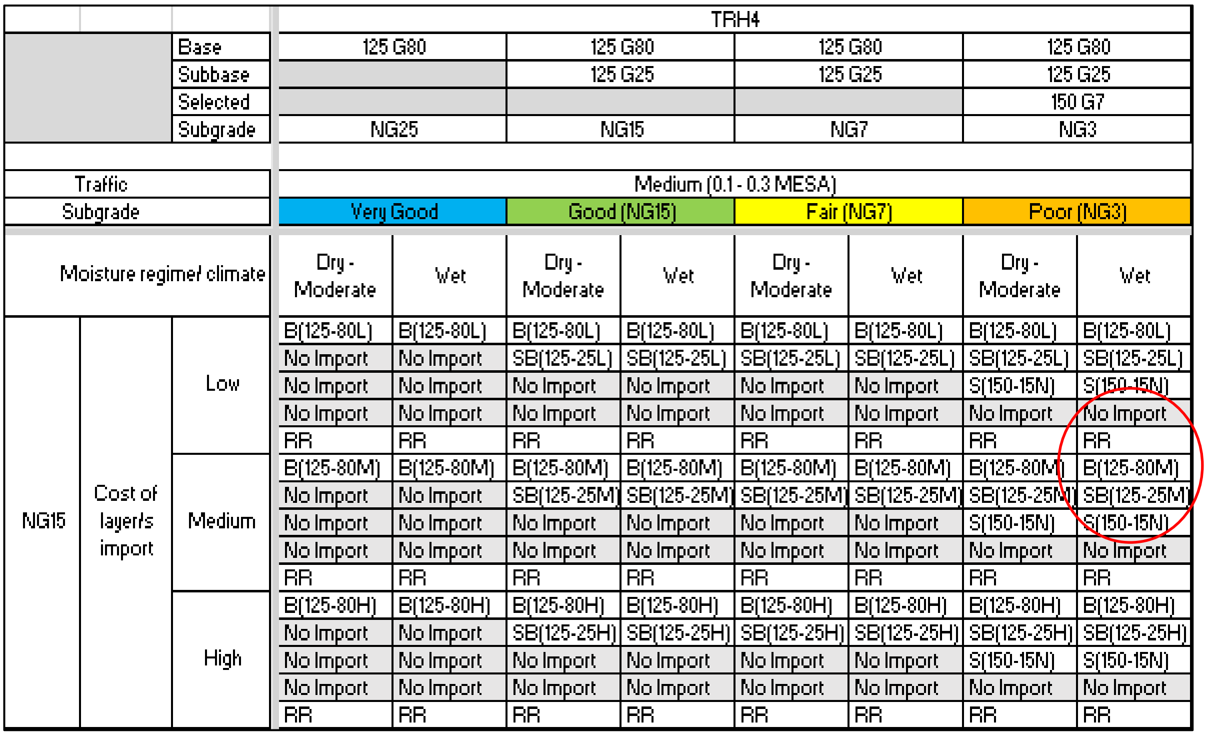


		Base	150 G31	150 G76	150 G31	150 G76	150 G31	150 G76	150 G31	150 G76
		Subbase	150 G5	150 G14	150 G5	150 G14	150 G5	150 G14	150 G5	150 G14
		Selected								
		Subgrade	NG25		NG15		NG7		NG3	
		Traffic	Medium (0.1 - 0.3 MESA)							
		Subgrade	VG (NG30)	VG (NG30)	Good (NG15)	Good (NG15)	Fair (NG15)	Fair (NG7)	Poor (NG7)	Poor (NG3)
		Moisture regime/ climate	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
NG15	Cost of layer/s import	Low	20.25	24.75	20.25	24.75	20.25	24.75	20.25	24.75
			0.00	0.00	0.00	0.00	0.00	16.50	16.50	16.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
		Medium	28.50	33.00	28.50	33.00	28.50	33.00	28.50	33.00
			0.00	0.00	0.00	0.00	0.00	16.50	16.50	16.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
		High	50.63	55.13	50.63	55.13	50.63	55.13	50.63	55.13
			0.00	0.00	0.00	0.00	0.00	16.50	16.50	16.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50

4. TRH4

The pavement structure for the given traffic class and wet environment is selected from the TRH4 catalogue as shown in Table 35.

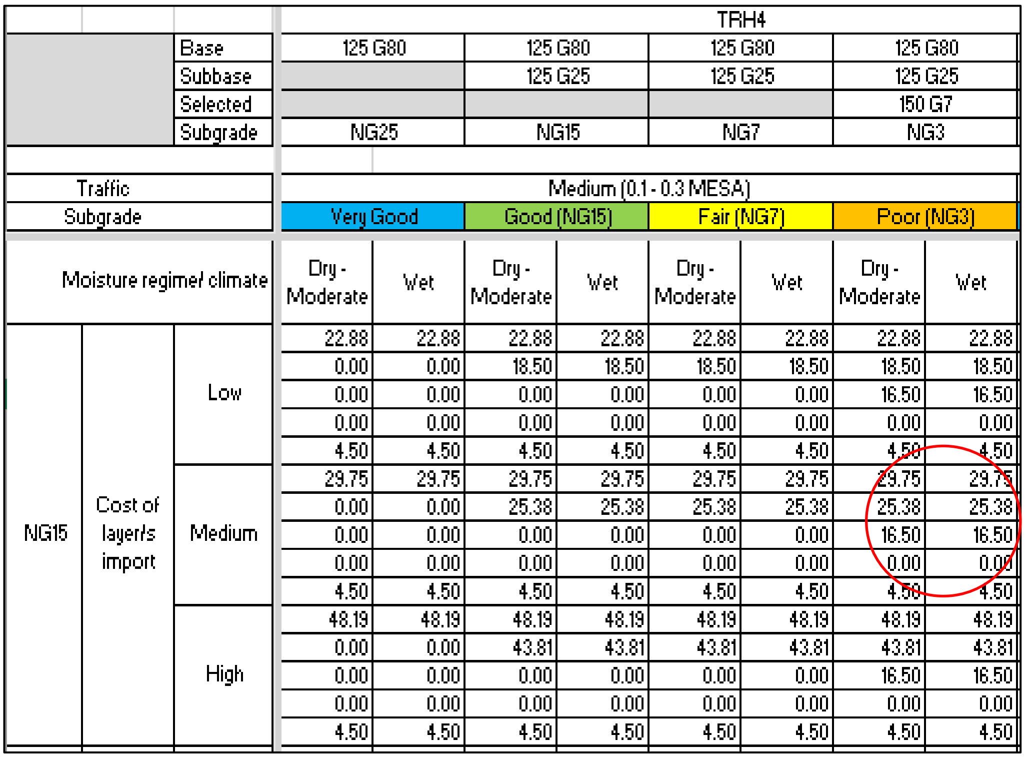
Table 35 Required pavement structure according to TRH4 design



			TRH4							
		Base	125 G80		125 G80		125 G80		125 G80	
		Subbase			125 G25		125 G25		125 G25	
		Selected							150 G7	
		Subgrade	NG25		NG15		NG7		NG3	
Traffic			Medium (0.1 - 0.3 MESA)							
Subgrade			Very Good		Good (NG15)		Fair (NG7)		Poor (NG3)	
Moisture regime/ climate			Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
NG15	Cost of layer/s import	Low	B(125-80L)	B(125-80L)	B(125-80L)	B(125-80L)	B(125-80L)	B(125-80L)	B(125-80L)	B(125-80L)
			No Import	No Import	SB(125-25L)	SB(125-25L)	SB(125-25L)	SB(125-25L)	SB(125-25L)	SB(125-25L)
			No Import	No Import	No Import	No Import	No Import	No Import	S(150-15N)	S(150-15N)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR
		Medium	B(125-80M)	B(125-80M)	B(125-80M)	B(125-80M)	B(125-80M)	B(125-80M)	B(125-80M)	B(125-80M)
			No Import	No Import	SB(125-25M)	SB(125-25M)	SB(125-25M)	SB(125-25M)	SB(125-25M)	SB(125-25M)
			No Import	No Import	No Import	No Import	No Import	No Import	S(150-15N)	S(150-15N)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR
		High	B(125-80H)	B(125-80H)	B(125-80H)	B(125-80H)	B(125-80H)	B(125-80H)	B(125-80H)	B(125-80H)
			No Import	No Import	SB(125-25H)	SB(125-25H)	SB(125-25H)	SB(125-25H)	SB(125-25H)	SB(125-25H)
			No Import	No Import	No Import	No Import	No Import	No Import	S(150-15N)	S(150-15N)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR

Similar to the process described under DN-DCP, the cost for each layer is calculated.

Table 36 Costs of different layers in the required pavement structure (TRH4)

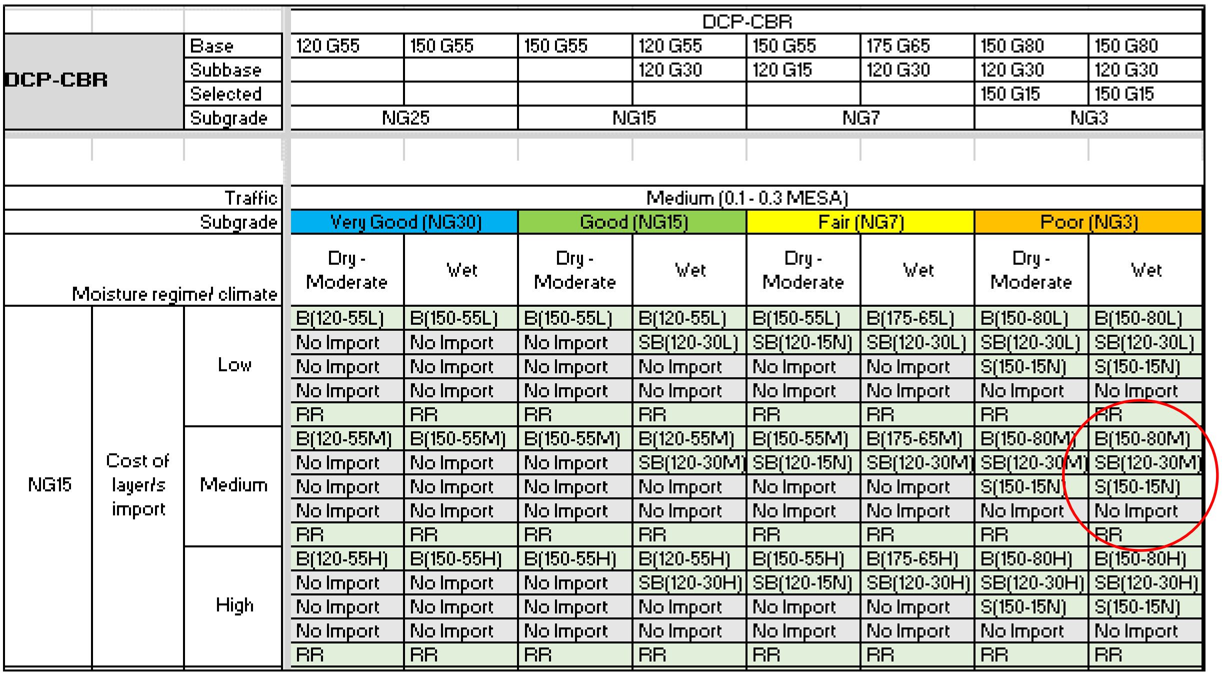


			TRH4							
		Base	125 G80		125 G80		125 G80		125 G80	
		Subbase			125 G25		125 G25		125 G25	
		Selected							150 G7	
		Subgrade	NG25		NG15		NG7		NG3	
Traffic			Medium (0.1 - 0.3 MESA)							
Subgrade			Very Good		Good (NG15)		Fair (NG7)		Poor (NG3)	
Moisture regime/ climate			Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
NG15	Cost of layer/s import	Low	22.88	22.88	22.88	22.88	22.88	22.88	22.88	22.88
			0.00	0.00	18.50	18.50	18.50	18.50	18.50	18.50
			0.00	0.00	0.00	0.00	0.00	0.00	16.50	16.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
		Medium	29.75	29.75	29.75	29.75	29.75	29.75	29.75	29.75
			0.00	0.00	25.38	25.38	25.38	25.38	25.38	25.38
			0.00	0.00	0.00	0.00	0.00	0.00	16.50	16.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
		High	48.19	48.19	48.19	48.19	48.19	48.19	48.19	48.19
			0.00	0.00	43.81	43.81	43.81	43.81	43.81	43.81
			0.00	0.00	0.00	0.00	0.00	0.00	16.50	16.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50

5. DCP-CBR

The pavement structure for the given traffic class and wet environment is selected from the relevant catalogue as shown in Table 37.

Table 37 Required pavement structure according to DCP-CBR design

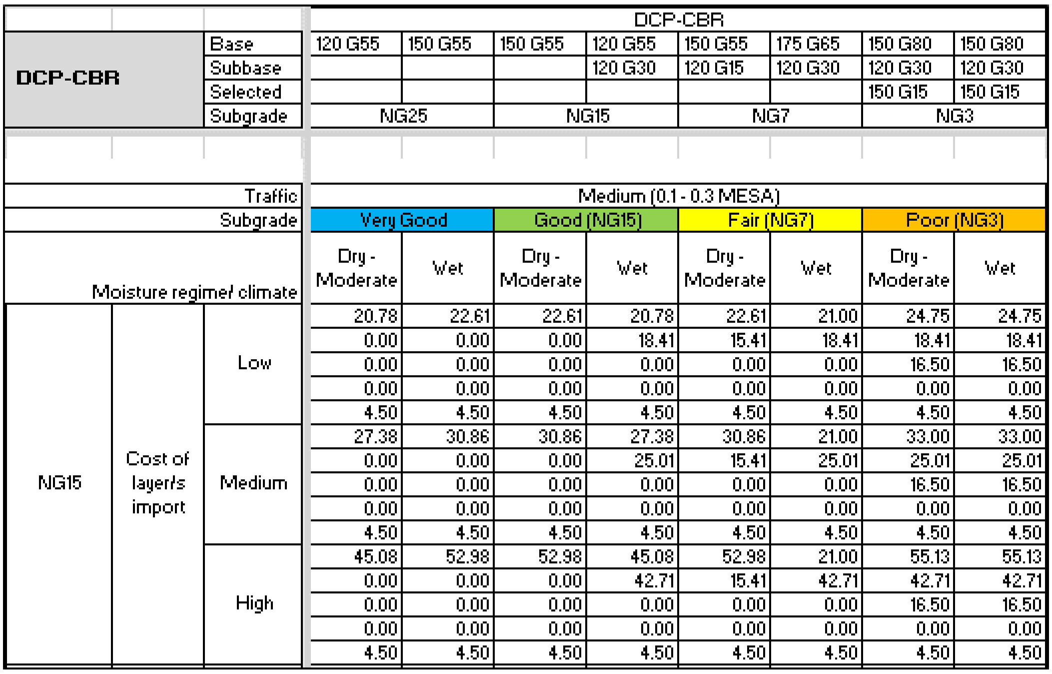


			DCP-CBR							
DCP-CBR		Base	120 G55	150 G55	150 G55	120 G55	150 G55	175 G65	150 G80	150 G80
		Subbase				120 G30	120 G15	120 G30	120 G30	120 G30
		Selected							150 G15	150 G15
		Subgrade	NG25		NG15		NG7		NG3	
		Traffic	Medium (0.1 - 0.3 MESA)							
		Subgrade	Very Good (NG30)		Good (NG15)		Fair (NG7)		Poor (NG3)	
		Moisture regime/ climate	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
NG15	Cost of layer/s import	Low	B(120-55L)	B(150-55L)	B(150-55L)	B(120-55L)	B(150-55L)	B(175-65L)	B(150-80L)	B(150-80L)
			No Import	No Import	No Import	SB(120-30L)	SB(120-15N)	SB(120-30L)	SB(120-30L)	SB(120-30L)
			No Import	No Import	No Import	No Import	No Import	No Import	S(150-15N)	S(150-15N)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR
		Medium	B(120-55M)	B(150-55M)	B(150-55M)	B(120-55M)	B(150-55M)	B(175-65M)	B(150-80M)	B(150-80M)
			No Import	No Import	No Import	SB(120-30M)	SB(120-15N)	SB(120-30M)	SB(120-30M)	SB(120-30M)
			No Import	No Import	No Import	No Import	No Import	No Import	S(150-15N)	S(150-15N)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR
		High	B(120-55H)	B(150-55H)	B(150-55H)	B(120-55H)	B(150-55H)	B(175-65H)	B(150-80H)	B(150-80H)
			No Import	No Import	No Import	SB(120-30H)	SB(120-15N)	SB(120-30H)	SB(120-30H)	SB(120-30H)
			No Import	No Import	No Import	No Import	No Import	No Import	S(150-15N)	S(150-15N)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR

In this case, the base and subbase must be imported (medium haul distance), while the selected layer will be imported at free-haul distance.

The cost per layer (Rand per m^2) is calculated as described under DCP-DN.

Table 38 Costs of different layers in the required pavement structure (DCP-CBR)



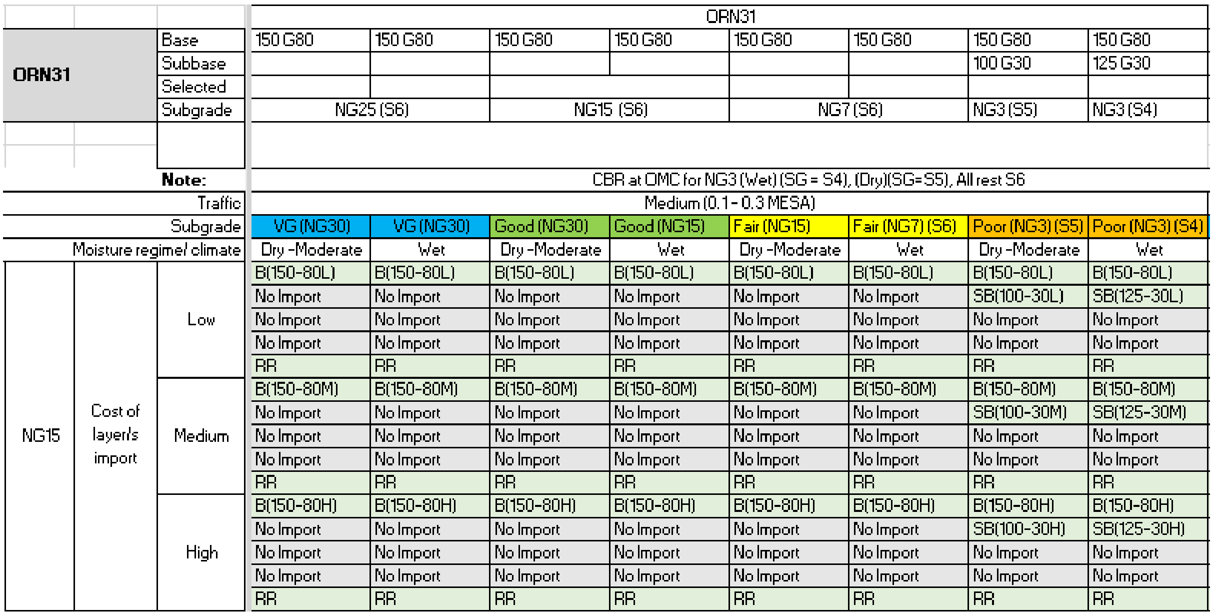
			DCP-CBR							
DCP-CBR		Base	120 G55	150 G55	150 G55	120 G55	150 G55	175 G65	150 G80	150 G80
		Subbase				120 G30	120 G15	120 G30	120 G30	120 G30
		Selected							150 G15	150 G15
		Subgrade	NG25		NG15		NG7		NG3	
		Traffic	Medium (0.1 - 0.3 MESA)							
		Subgrade	Very Good		Good (NG15)		Fair (NG7)		Poor (NG3)	
		Moisture regime/ climate	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
NG15	Cost of layer/s import	Low	20.78	22.61	22.61	20.78	22.61	21.00	24.75	24.75
			0.00	0.00	0.00	18.41	15.41	18.41	18.41	18.41
			0.00	0.00	0.00	0.00	0.00	0.00	16.50	16.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
		Medium	27.38	30.86	30.86	27.38	30.86	21.00	33.00	33.00
			0.00	0.00	0.00	25.01	15.41	25.01	25.01	25.01
			0.00	0.00	0.00	0.00	0.00	0.00	16.50	16.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
		High	45.08	52.98	52.98	45.08	52.98	21.00	55.13	55.13
			0.00	0.00	0.00	42.71	15.41	42.71	42.71	42.71
			0.00	0.00	0.00	0.00	0.00	0.00	16.50	16.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50

6. ORN31

In the case of ORN31, the required pavement structure is dependent on the selected subgrade class.

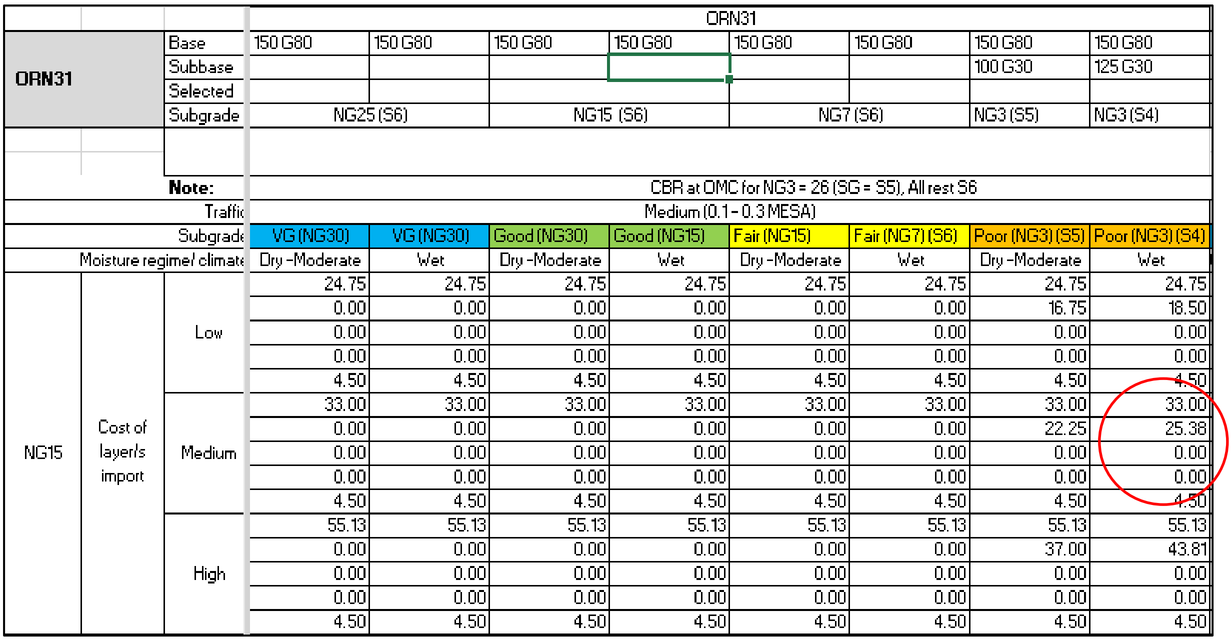
The required pavement structures for 0.3 MESA and layer costs are shown in Table 39

Table 39 Required pavement structure according to ORN31 design



			ORN31							
ORN31		Base	150 G80	150 G80	150 G80	150 G80	150 G80	150 G80	150 G80	150 G80
		Subbase							100 G30	125 G30
		Selected								
		Subgrade	NG25 (S6)		NG15 (S6)		NG7 (S6)		NG3 (S5)	NG3 (S4)
		Note:	CBR at OMC for NG3 (Wet) (SG = S4), (Dry)(SG=S5), All rest S6							
		Traffic	Medium (0.1 - 0.3 MESA)							
		Subgrade	VG (NG30)	VG (NG30)	Good (NG30)	Good (NG15)	Fair (NG15)	Fair (NG7) (S6)	Poor (NG3) (S5)	Poor (NG3) (S4)
		Moisture regime/ climate	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
NG15	Cost of layer/s import	Low	B(150-80L)	B(150-80L)	B(150-80L)	B(150-80L)	B(150-80L)	B(150-80L)	B(150-80L)	B(150-80L)
			No Import	No Import	No Import	No Import	No Import	No Import	SB(100-30L)	SB(125-30L)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR
		Medium	B(150-80M)	B(150-80M)	B(150-80M)	B(150-80M)	B(150-80M)	B(150-80M)	B(150-80M)	B(150-80M)
			No Import	No Import	No Import	No Import	No Import	No Import	SB(100-30M)	SB(125-30M)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR
		High	B(150-80H)	B(150-80H)	B(150-80H)	B(150-80H)	B(150-80H)	B(150-80H)	B(150-80H)	B(150-80H)
			No Import	No Import	No Import	No Import	No Import	No Import	SB(100-30H)	SB(125-30H)
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			No Import	No Import	No Import	No Import	No Import	No Import	No Import	No Import
			RR	RR	RR	RR	RR	RR	RR	RR

Table 40 Costs of different layers in the required pavement structure (ORN31)



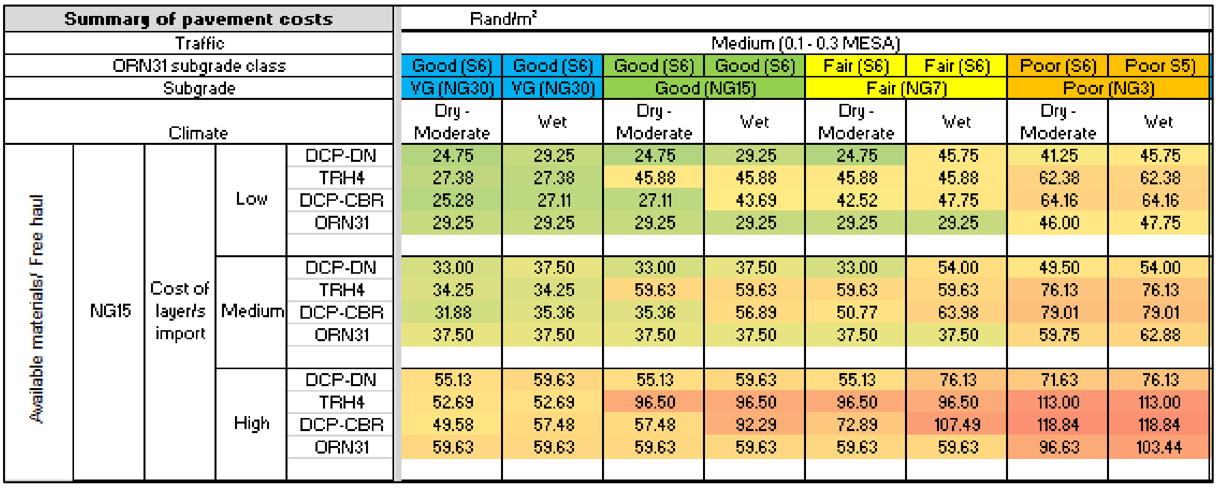
			ORN31							
ORN31		Base	150 G80	150 G80	150 G80	150 G80	150 G80	150 G80	150 G80	150 G80
		Subbase							100 G30	125 G30
		Selected								
		Subgrade	NG25 (S6)		NG15 (S6)		NG7 (S6)		NG3 (S5)	NG3 (S4)
		Note:	CBR at OMC for NG3 = 26 (SG = S5), All rest S6							
		Traffi	Medium (0.1 - 0.3 MESA)							
		Subgrad	VG (NG30)	VG (NG30)	Good (NG30)	Good (NG15)	Fair (NG15)	Fair (NG7) (S6)	Poor (NG3) (S5)	Poor (NG3) (S4)
		Moisture regime/ climat	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
NG15	Cost of layer/s import	Low	24.75	24.75	24.75	24.75	24.75	24.75	24.75	24.75
			0.00	0.00	0.00	0.00	0.00	0.00	16.75	18.50
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
		Medium	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00
			0.00	0.00	0.00	0.00	0.00	0.00	22.25	25.38
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
		High	55.13	55.13	55.13	55.13	55.13	55.13	55.13	55.13
			0.00	0.00	0.00	0.00	0.00	0.00	37.00	43.81
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50

7. Cost comparison

a) Pavement layer costs

The total pavement layer costs are calculated for each design method as shown in Table 41.

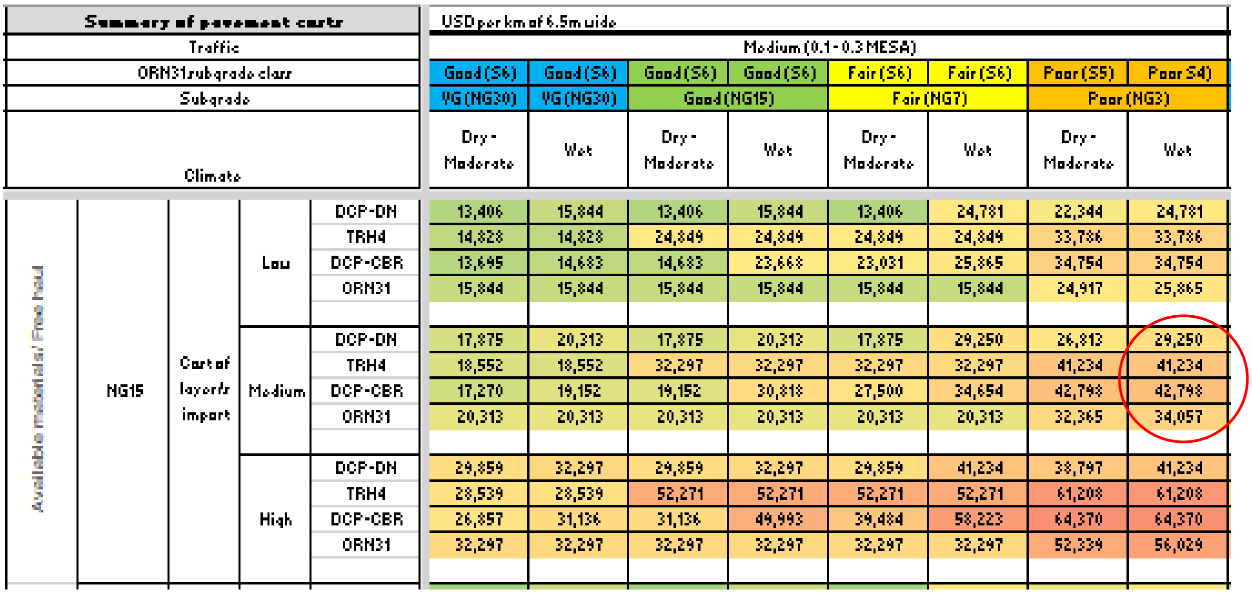
Table 41 Summary of pavement layer cost in Rand per m^2



Summary of pavement costs					Rand/m^2							
Traffic					Medium (0.1 - 0.3 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S6)	Poor S5)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Low	DCP-DN	24.75	29.25	24.75	29.25	24.75	45.75	41.25	45.75
				TRH4	27.38	27.38	45.88	45.88	45.88	45.88	62.38	62.38
				DCP-CBR	25.28	27.11	27.11	43.69	42.52	47.75	64.16	64.16
				ORN31	29.25	29.25	29.25	29.25	29.25	29.25	46.00	47.75
			Medium	DCP-DN	33.00	37.50	33.00	37.50	33.00	54.00	49.50	54.00
				TRH4	34.25	34.25	59.63	59.63	59.63	59.63	76.13	76.13
				DCP-CBR	31.88	35.36	35.36	56.89	50.77	63.98	79.01	79.01
				ORN31	37.50	37.50	37.50	37.50	37.50	37.50	59.75	62.88
			High	DCP-DN	55.13	59.63	55.13	59.63	55.13	76.13	71.63	76.13
				TRH4	52.69	52.69	96.50	96.50	96.50	96.50	113.00	113.00
				DCP-CBR	49.58	57.48	57.48	92.29	72.89	107.49	118.84	118.84
				ORN31	59.63	59.63	59.63	59.63	59.63	59.63	96.63	103.44

All costs are then converted to USD as shown inTable 42.

Table 42 Summary of pavement layer costs in USD per km

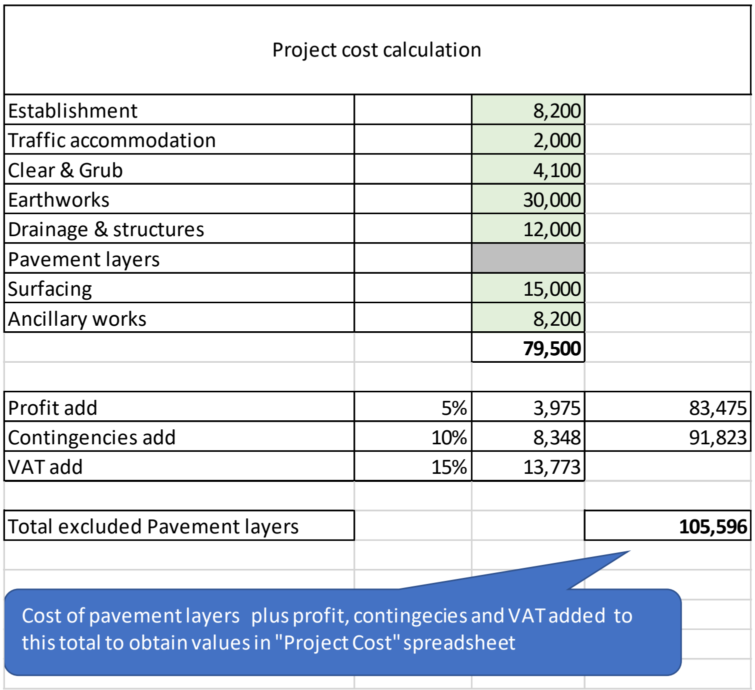


Summary of pavement costs					USD per km of 6.5m wide							
Traffic					Medium (0.1 - 0.3 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Low	DCP-DN	13,406	15,844	13,406	15,844	13,406	24,781	22,344	24,781
				TRH4	14,828	14,828	24,849	24,849	24,849	24,849	33,786	33,786
				DCP-CBR	13,695	14,683	14,683	23,668	23,031	25,865	34,754	34,754
				ORN31	15,844	15,844	15,844	15,844	15,844	15,844	24,917	25,865
			Medium	DCP-DN	17,875	20,313	17,875	20,313	17,875	29,250	26,813	29,250
				TRH4	18,552	18,552	32,297	32,297	32,297	32,297	41,234	41,234
				DCP-CBR	17,270	19,152	19,152	30,818	27,500	34,654	42,798	42,798
				ORN31	20,313	20,313	20,313	20,313	20,313	20,313	32,365	34,057
			High	DCP-DN	29,859	32,297	29,859	32,297	29,859	41,234	38,797	41,234
				TRH4	28,539	28,539	52,271	52,271	52,271	52,271	61,208	61,208
				DCP-CBR	26,857	31,136	31,136	49,993	39,484	58,223	64,370	64,370
				ORN31	32,297	32,297	32,297	32,297	32,297	32,297	52,339	56,029

b) Project costs

Total project costs comprise several additional items in addition to the pavement layer costs. The costs of the additional items, as estimated and shown in Table 43, are added to the pavement layer costs to obtain the total project costs as shown in Table 44.

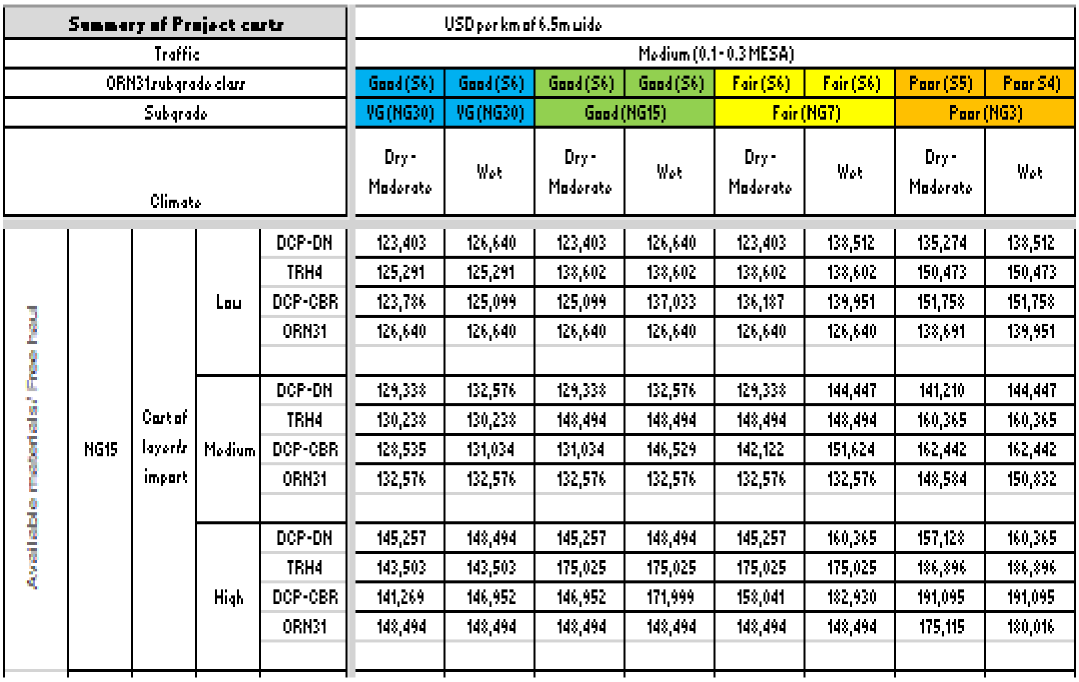
Table 43 Cost items additional to pavement layers



Project cost calculation			
Establishment		8,200	
Traffic accommodation		2,000	
Clear & Grub		4,100	
Earthworks		30,000	
Drainage & structures		12,000	
Pavement layers			
Surfacing		15,000	
Ancillary works		8,200	
		79,500	
Profit add	5%	3,975	83,475
Contingencies add	10%	8,348	91,823
VAT add	15%	13,773	
Total excluded Pavement layers			**105,596**

Cost of pavement layers plus profit, contingecies and VAT added to this total to obtain values in "Project Cost" spreadsheet

Table 44 Summary of project costs per km



Summary of Project costs					USD per km of 6.5m wide							
Traffic					Medium (0.1-0.3 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layers import	Low	DCP-DN	123,403	126,640	123,403	126,640	123,403	138,512	135,274	138,512
				TRH4	125,291	125,291	138,602	138,602	138,602	138,602	150,473	150,473
				DCP-CBR	123,786	125,099	125,099	137,033	136,187	139,951	151,758	151,758
				ORN31	126,640	126,640	126,640	126,640	126,640	126,640	138,691	139,951
			Medium	DCP-DN	129,338	132,576	129,338	132,576	129,338	144,447	141,210	144,447
				TRH4	130,238	130,238	148,494	148,494	148,494	148,494	160,365	160,365
				DCP-CBR	128,535	131,034	131,034	146,529	142,122	151,624	162,442	162,442
				ORN31	132,576	132,576	132,576	132,576	132,576	132,576	148,584	150,832
			High	DCP-DN	145,257	148,494	145,257	148,494	145,257	160,365	157,128	160,365
				TRH4	143,503	143,503	175,025	175,025	175,025	175,025	186,896	186,896
				DCP-CBR	141,269	146,952	146,952	171,999	158,041	182,930	191,095	191,095
				ORN31	148,494	148,494	148,494	148,494	148,494	148,494	175,115	180,016

The information for the wet environment is presented in a graphical format for different traffic classes and subgrade conditions in Figure 11, Figure 12 and Figure 13.

The information for the dry-moderate environment is presented in a graphical format for different traffic classes and subgrade conditions in Figure 14, Figure 15 and Figure 16.

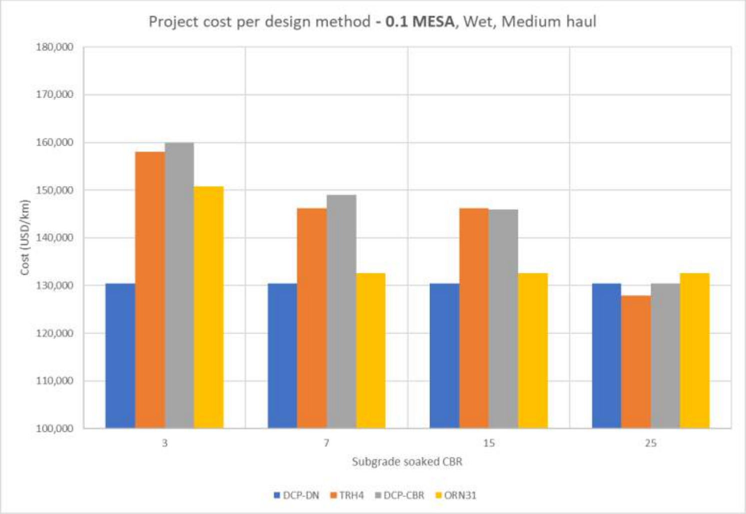


Figure 11 km cost, 0.1 MESA, Wet, Medium haul

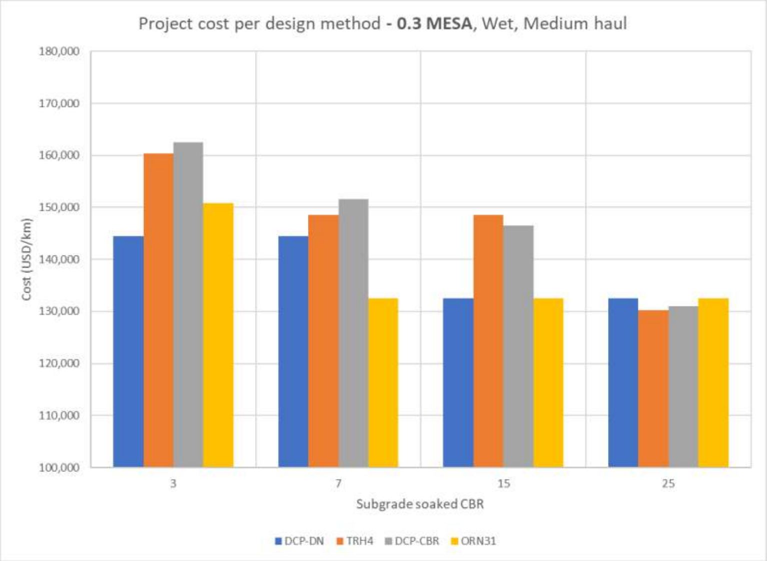


Figure 12 km cost, 0.3 MESA, Wet, Medium haul

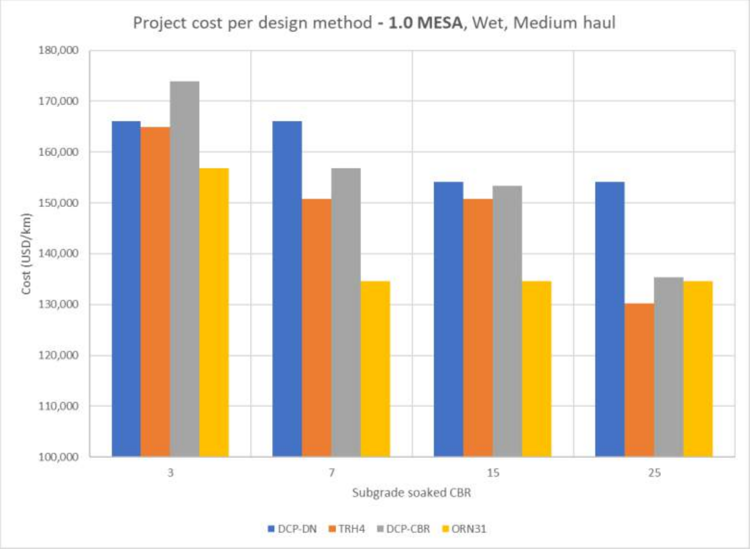


Figure 13 km cost, 1 MESA, Wet, Medium haul

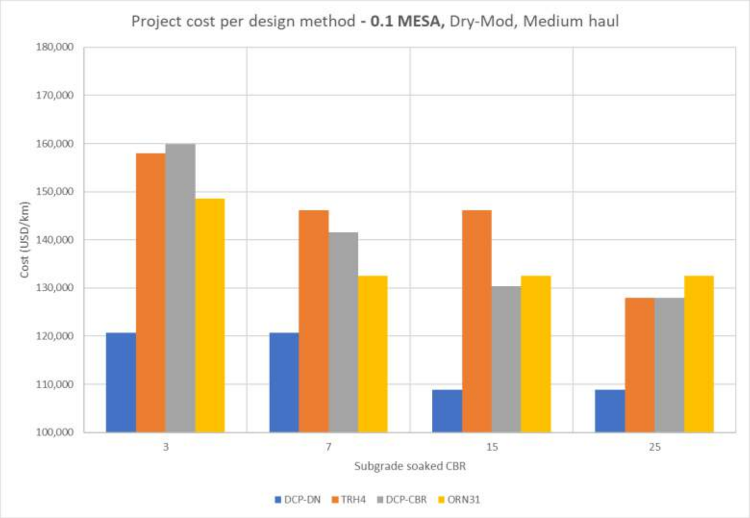


Figure 14 km cost, 0.1 MESA, Dry-Moderate, Medium haul

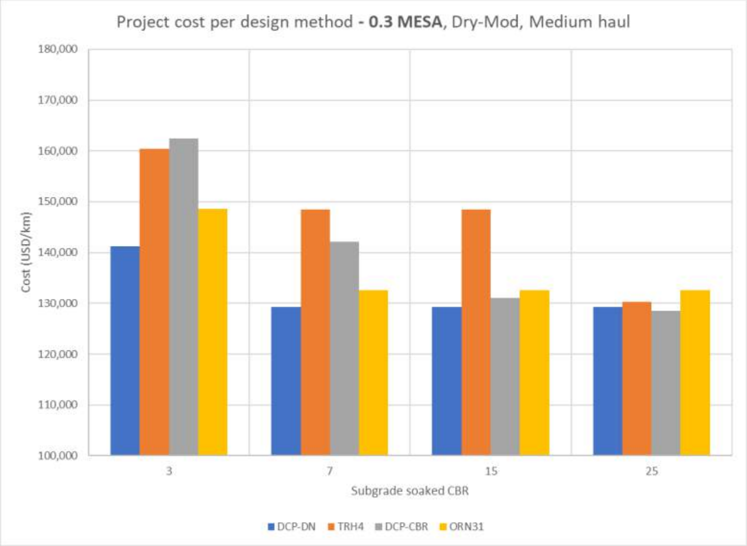


Figure 15 km cost, 0.3 MESA, Dry-Moderate, Medium haul

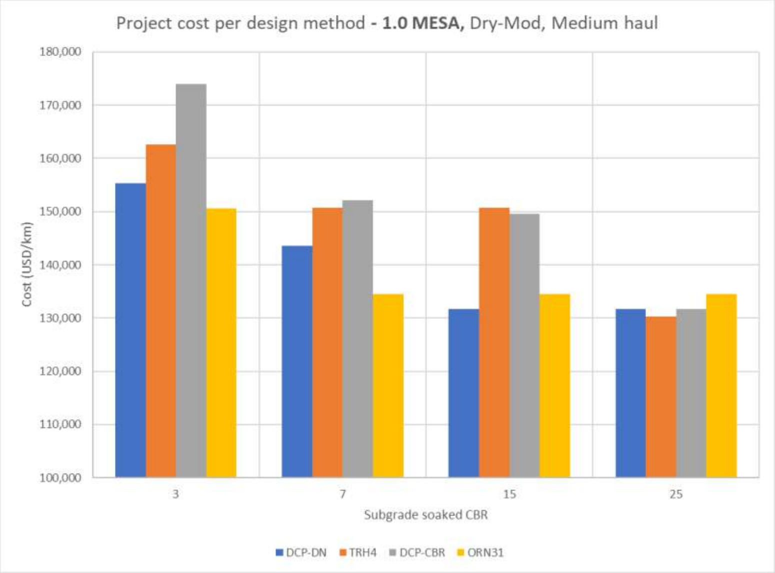


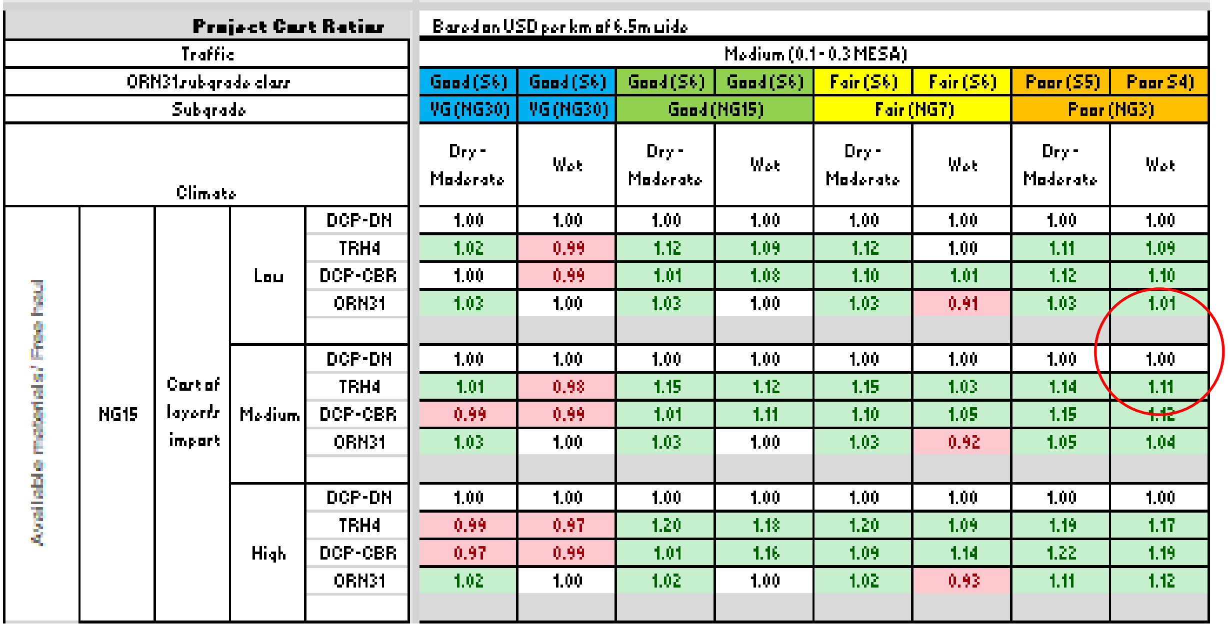
Figure 16 km cost, 1.0 MESA, Dry-Moderate, Medium haul

c) Cost ratios

The ratio, relative to the project costs (as per DCP-DN design) is calculated for each scenario as shown in Table 45.

For the particular scenario, ORN31 results in 4% additional costs whereas TRH4 and DCP-CBR result respectively in 11% and 12% additional costs

Table 45 Project cost ratios

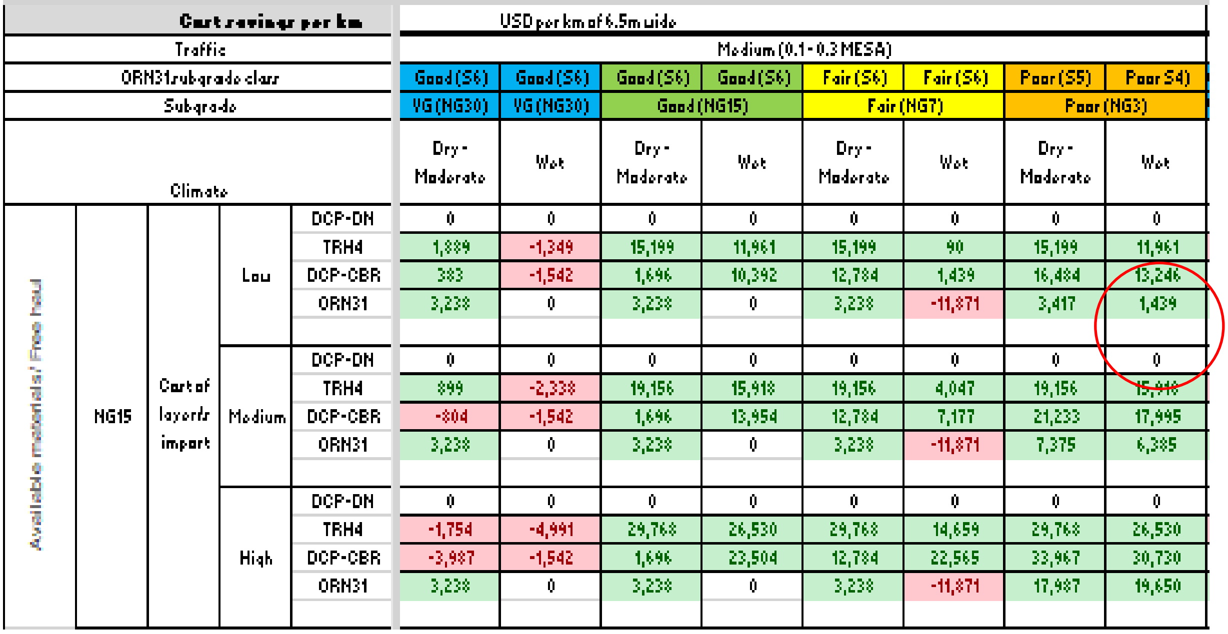


Project Cost Ratios					Based on USD per km of 6.5m wide							
Traffic					Medium (0.1 - 0.3 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layers import	Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.02	0.99	1.12	1.09	1.12	1.00	1.11	1.09
				DCP-CBR	1.00	0.99	1.01	1.08	1.10	1.01	1.12	1.10
				ORN31	1.03	1.00	1.03	1.00	1.03	0.91	1.03	1.01
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.01	0.98	1.15	1.12	1.15	1.03	1.14	1.11
				DCP-CBR	0.99	0.99	1.01	1.11	1.10	1.05	1.15	1.12
				ORN31	1.03	1.00	1.03	1.00	1.03	0.92	1.05	1.04
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	0.99	0.97	1.20	1.18	1.20	1.09	1.19	1.17
				DCP-CBR	0.97	0.99	1.01	1.16	1.09	1.14	1.22	1.19
				ORN31	1.02	1.00	1.02	1.00	1.02	0.93	1.11	1.12

d) Cost savings

Project cost savings by using the DCP-DN design method have been calculated, based on the calculated pavement layer costs and estimated additional cost items as discussed under Section b). (See Table 46)

Table 46 Project cost savings per km



Cost savings per km					USD per km of 6.5m wide							
Traffic					Medium (0.1 - 0.3 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layers import	Low	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	1,889	-1,349	15,199	11,961	15,199	90	15,199	11,961
				DCP-CBR	383	-1,542	1,696	10,392	12,784	1,439	16,484	13,246
				ORN31	3,238	0	3,238	0	3,238	-11,871	3,417	1,439
			Medium	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	899	-2,338	19,156	15,918	19,156	4,047	19,156	15,918
				DCP-CBR	-804	-1,542	1,696	13,954	12,784	7,177	21,233	17,995
				ORN31	3,238	0	3,238	0	3,238	-11,871	7,375	6,385
			High	DCP-DN	0	0	0	0	0	0	0	0
				TRH4	-1,754	-4,991	29,768	26,530	29,768	14,659	29,768	26,530
				DCP-CBR	-3,987	-1,542	1,696	23,504	12,784	22,565	33,967	30,730
				ORN31	3,238	0	3,238	0	3,238	-11,871	17,987	19,650

Annex H – Pavement Costs and Cost Ratios, Project Cost and Cost ratios and Project Cost Savings/km)

(1) Pavement Costs

Summary of pavement costs					USD per km of 6.5m wide																							
Traffic					Low (< 0.1 MESA)								Medium (0.1 - 0.3 MESA)								High (0.3 - 1.0 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	13 813	11 375	13 813	11 375	22 750	20 313	22 750	13 116	23 563	13 116	23 563	22 054	32 500	30 991	32 500
				TRH4	12 458	12 458	20 786	20 786	20 786	20 786	29 724	29 724	13 135	13 135	21 464	21 464	21 464	21 464	30 401	30 401	13 135	13 135	22 073	22 073	22 073	22 073	31 010	31 688
				DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	31 098	31 098	13 116	13 749	21 464	22 097	22 054	23 390	35 212	35 212
				ORN31	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	14 229	14 229	14 229	14 229	14 229	14 229	21 948	23 390
			Low	DCP-DN	2 438	14 219	2 438	14 219	11 375	14 219	11 375	14 219	13 406	15 844	13 406	15 844	13 406	24 781	22 344	24 781	15 147	27 625	15 147	27 625	24 085	36 563	33 022	36 563
				TRH4	13 813	13 813	23 833	23 833	23 833	23 833	32 771	32 771	14 828	14 828	24 849	24 849	24 849	24 849	33 786	33 786	14 828	14 828	25 797	25 797	25 797	25 797	34 734	35 750
				DCP-CBR	13 245	14 219	14 219	23 217	22 567	24 656	32 839	32 839	13 695	14 683	14 683	23 668	23 031	25 865	34 754	34 754	15 147	16 458	25 120	26 430	26 116	28 130	40 290	40 290
				ORN31	15 844	15 844	15 844	15 844	15 844	15 844	24 917	25 865	15 844	15 844	15 844	15 844	15 844	15 844	24 917	25 865	16 599	16 599	16 599	16 599	16 599	16 599	25 672	28 130
			Medium	DCP-DN	2 438	18 688	2 438	18 688	11 375	18 688	11 375	18 688	17 875	20 313	17 875	20 313	17 875	29 250	26 813	29 250	19 616	36 563	19 616	36 563	28 554	45 500	37 491	45 500
				TRH4	16 792	16 792	30 536	30 536	30 536	30 536	39 474	39 474	18 552	18 552	32 297	32 297	32 297	32 297	41 234	41 234	18 552	18 552	33 990	33 990	33 990	33 990	42 927	44 688
				DCP-CBR	16 820	18 688	18 688	30 367	27 035	32 700	40 883	40 883	17 270	19 152	19 152	30 818	27 500	34 654	42 798	42 798	19 616	22 416	33 164	35 964	35 054	38 557	51 462	51 462
				ORN31	20 313	20 313	20 313	20 313	20 313	20 313	32 365	34 057	20 313	20 313	20 313	20 313	20 313	20 313	32 365	34 057	21 813	21 813	21 813	21 813	21 813	21 813	33 865	38 557
			High	DCP-DN	2 438	30 672	2 438	30 672	11 375	30 672	11 375	30 672	29 859	32 297	29 859	32 297	29 859	41 234	38 797	41 234	31 600	60 531	31 600	60 531	40 538	69 469	49 475	69 469
				TRH4	24 781	24 781	48 513	48 513	48 513	48 513	57 451	57 451	28 539	28 539	52 271	52 271	52 271	52 271	61 208	61 208	28 539	28 539	55 961	55 961	55 961	55 961	64 898	68 656
				DCP-CBR	26 407	30 672	30 672	49 542	39 020	54 272	62 455	62 455	26 857	31 136	31 136	49 993	39 484	58 223	64 370	64 370	31 600	38 395	54 736	61 530	59 022	66 520	81 423	81 423
				ORN31	32 297	32 297	32 297	32 297	32 297	32 297	52 339	56 029	32 297	32 297	32 297	32 297	32 297	32 297	52 339	56 029	35 794	35 794	35 794	35 794	35 794	35 794	55 836	66 520
	NG25/30	Cost of layer/s import	Zero Haulage	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	13 813	11 375	13 813	11 375	22 750	20 313	22 750	13 116	23 563	13 116	23 563	22 054	32 500	30 991	32 500
				TRH4	12 458	12 458	20 786	20 786	20 786	20 786	29 724	29 724	13 135	13 135	21 464	21 464	21 464	21 464	30 401	30 401	13 135	13 135	22 073	22 073	22 073	22 073	31 010	31 688
				DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	31 098	31 098	13 116	13 749	21 464	22 097	22 054	23 390	35 212	35 212
				ORN31	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	14 229	14 229	14 229	14 229	14 229	14 229	21 948	23 390
			Low	DCP-DN	2 438	14 219	2 438	14 219	11 375	14 219	11 375	14 219	11 375	15 844	11 375	15 844	11 375	24 781	20 313	24 781	15 147	27 625	15 147	27 625	24 085	36 563	33 022	36 563
				TRH4	13 813	13 813	22 141	22 141	22 141	22 141	31 078	31 078	14 828	14 828	23 156	23 156	23 156	23 156	32 094	32 094	14 828	14 828	23 766	23 766	23 766	23 766	32 703	33 719
				DCP-CBR	13 245	14 219	14 219	21 592	22 567	23 031	31 214	31 214	13 695	14 683	14 683	22 043	23 031	24 240	33 129	33 129	15 147	16 458	23 495	24 805	24 085	26 099	37 920	37 920
				ORN31	15 844	15 844	15 844	15 844	15 844	15 844	23 563	24 172	15 844	15 844	15 844	15 844	15 844	15 844	23 563	24 172	16 599	16 599	16 599	16 599	16 599	16 599	24 318	26 099
			Medium	DCP-DN	2 438	18 688	2 438	18 688	11 375	18 688	11 375	18 688	11 375	20 313	11 375	20 313	11 375	29 250	20 313	29 250	19 616	36 563	19 616	36 563	28 554	45 500	37 491	45 500
				TRH4	16 792	16 792	25 120	25 120	25 120	25 120	34 057	34 057	18 552	18 552	26 880	26 880	26 880	26 880	35 818	35 818	18 552	18 552	27 490	27 490	27 490	27 490	36 427	38 188
				DCP-CBR	16 820	18 688	18 688	25 167	27 035	27 500	35 683	35 683	17 270	19 152	19 152	25 618	27 500	29 454	37 598	37 598	19 616	22 416	27 964	30 764	28 554	32 057	43 879	43 879
				ORN31	20 313	20 313	20 313	20 313	20 313	20 313	28 031	28 641	20 313	20 313	20 313	20 313	20 313	20 313	28 031	28 641	21 813	21 813	21 813	21 813	21 813	21 813	29 531	32 057
			High	DCP-DN	2 438	30 672	2 438	30 672	11 375	30 672	11 375	30 672	11 375	32 297	11 375	32 297	11 375	41 234	20 313	41 234	31 600	60 531	31 600	60 531	40 538	69 469	49 475	69 469
				TRH4	24 781	24 781	33 109	33 109	33 109	33 109	42 047	42 047	28 539	28 539	36 867	36 867	36 867	36 867	45 805	45 805	28 539	28 539	36 867	36 867	36 867	36 867	45 805	49 563
				DCP-CBR	26 407	30 672	30 672	34 755	39 020	39 484	47 667	47 667	26 857	31 136	31 136	35 205	39 484	43 435	49 582	49 582	31 600	38 395	39 948	46 743	40 538	48 036	59 858	59 858
				ORN31	32 297	32 297	32 297	32 297	32 297	32 297	40 016	40 625	32 297	32 297	32 297	32 297	32 297	32 297	40 016	40 625	35 794	35 794	35 794	35 794	35 794	35 794	43 513	48 036
	NG45	Cost of layer/s import	Zero Haulage	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	13 813	11 375	13 813	11 375	22 750	20 313	22 750	13 116	23 563	13 116	23 563	22 054	32 500	30 991	32 500
				TRH4	12 458	12 458	20 786	20 786	20 786	20 786	29 724	29 724	13 135	13 135	21 464	21 464	21 464	21 464	30 401	30 401	13 135	13 135	22 073	22 073	22 073	22 073	31 010	31 688
				DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	31 098	31 098	13 116	13 749	21 464	22 097	22 054	23 390	35 212	35 212
				ORN31	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	14 229	14 229	14 229	14 229	14 229	14 229	21 948	23 390
			Low	DCP-DN	2 438	14 219	2 438	14 219	11 375	14 219	11 375	14 219	11 375	15 844	11 375	15 844	11 375	24 781	20 313	24 781	15 147	27 625	15 147	27 625	24 085	36 563	33 022	36 563
				TRH4	13 813	13 813	22 141	22 141	22 141	22 141	31 078	31 078	14 828	14 828	23 156	23 156	23 156	23 156	32 094	32 094	14 828	14 828	23 766	23 766	23 766	23 766	32 703	33 719
				DCP-CBR	11 620	12 188	12 188	19 967	20 535	23 031	31 214	31 214	13 695	14 683	14 683	22 043	23 031	24 240	33 129	33 129	15 147	16 458	23 495	24 805	24 085	26 099	37 920	37 920
				ORN31	15 844	15 844	15 844	15 844	15 844	15 844	23 563	24 172	15 844	15 844	15 844	15 844	15 844	15 844	23 563	24 172	16 599	16 599	16 599	16 599	16 599	16 599	24 318	26 099
			Medium	DCP-DN	2 438	18 688	2 438	18 688	11 375	18 688	11 375	18 688	11 375	20 313	11 375	20 313	11 375	29 250	20 313	29 250	19 616	36 563	19 616	36 563	28 554	45 500	37 491	45 500
				TRH4	16 792	16 792	25 120	25 120	25 120	25 120	34 057	34 057	18 552	18 552	26 880	26 880	26 880	26 880	35 818	35 818	18 552	18 552	27 490	27 490	27 490	27 490	36 427	38 188
				DCP-CBR	11 620	12 188	12 188	19 967	20 535	27 500	35 683	35 683	17 270	19 152	19 152	25 618	27 500	29 454	37 598	37 598	19 616	22 416	27 964	30 764	28 554	32 057	43 879	43 879
				ORN31	20 313	20 313	20 313	20 313	20 313	20 313	28 031	28 641	20 313	20 313	20 313	20 313	20 313	20 313	28 031	28 641	21 813	21 813	21 813	21 813	21 813	21 813	29 531	32 057
			High	DCP-DN	2 438	30 672	2 438	30 672	11 375	30 672	11 375	30 672	11 375	32 297	11 375	32 297	11 375	41 234	20 313	41 234	31 600	60 531	31 600	60 531	40 538	69 469	49 475	69 469
				TRH4	24 781	24 781	33 109	33 109	33 109	33 109	42 047	42 047	28 539	28 539	36 867	36 867	36 867	36 867	45 805	45 805	28 539	28 539	36 867	36 867	36 867	36 867	45 805	49 563
				DCP-CBR	11 620	12 188	12 188	19 967	20 535	39 484	47 667	47 667	26 857	31 136	31 136	35 205	39 484	43 435	49 582	49 582	31 600	38 395	39 948	46 743	40 538	48 036	59 858	59 858
				ORN31	32 297	32 297	32 297	32 297	32 297	32 297	40 016	40 625	32 297	32 297	32 297	32 297	32 297	32 297	40 016	40 625	35 794	35 794	35 794	35 794	35 794	35 794	43 513	48 036

(2) Pavement Costs (Cont'd)

Summary of pavement costs				USD per km of 6.5m wide																							
Traffic				Low (< 0.1 MESA)								Medium (0.1 - 0.3 MESA)								High (0.3 - 1.0 MESA)							
ORN31 subgrade class				Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade				VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate				Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
NG55	Cost of layer/s import	Zero Haulage	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	13 813	11 375	13 813	11 375	22 750	20 313	22 750	13 116	23 563	13 116	23 563	22 054	32 500	30 991	32 500
			TRH4	12 458	12 458	20 786	20 786	20 786	20 786	29 724	29 724	13 135	13 135	21 464	21 464	21 464	21 464	30 401	30 401	13 135	13 135	22 073	22 073	22 073	22 073	31 010	31 688
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	31 098	31 098	13 116	13 749	21 464	22 097	22 054	23 390	35 212	35 212
			ORN31	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	14 229	14 229	14 229	14 229	14 229	14 229	21 948	23 390
		Low	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	15 844	11 375	15 844	11 375	24 781	20 313	24 781	15 147	25 594	15 147	25 594	24 085	34 531	33 022	34 531
			TRH4	13 813	13 813	22 141	22 141	22 141	22 141	31 078	31 078	14 828	14 828	23 156	23 156	23 156	23 156	32 094	32 094	14 828	14 828	23 766	23 766	23 766	23 766	32 703	33 719
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	31 214	31 214	12 070	12 652	12 652	20 418	21 000	24 240	33 129	33 129	15 147	16 458	23 495	24 805	24 085	26 099	37 920	37 920
			ORN31	15 844	15 844	15 844	15 844	15 844	15 844	23 563	24 172	15 844	15 844	15 844	15 844	15 844	15 844	23 563	24 172	16 599	16 599	16 599	16 599	16 599	16 599	24 318	26 099
		Medium	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	20 313	11 375	20 313	11 375	29 250	20 313	29 250	19 616	30 063	19 616	30 063	28 554	39 000	37 491	39 000
			TRH4	16 792	16 792	25 120	25 120	25 120	25 120	34 057	34 057	18 552	18 552	26 880	26 880	26 880	26 880	35 818	35 818	18 552	18 552	27 490	27 490	27 490	27 490	36 427	38 188
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	35 683	35 683	12 070	12 652	12 652	20 418	21 000	29 454	37 598	37 598	19 616	22 416	27 964	30 764	28 554	32 057	43 879	43 879
			ORN31	20 313	20 313	20 313	20 313	20 313	20 313	28 031	28 641	20 313	20 313	20 313	20 313	20 313	20 313	28 031	28 641	21 813	21 813	21 813	21 813	21 813	21 813	29 531	32 057
		High	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	32 297	11 375	32 297	11 375	41 234	20 313	41 234	31 600	42 047	31 600	42 047	40 538	50 984	49 475	50 984
			TRH4	24 781	24 781	33 109	33 109	33 109	33 109	42 047	42 047	28 539	28 539	36 867	36 867	36 867	36 867	45 805	45 805	28 539	28 539	36 867	36 867	36 867	36 867	45 805	49 563
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	47 667	47 667	12 070	12 652	12 652	20 418	21 000	43 435	49 582	49 582	31 600	38 395	39 948	46 743	40 538	48 036	59 858	59 858
			ORN31	32 297	32 297	32 297	32 297	32 297	32 297	40 016	40 625	32 297	32 297	32 297	32 297	32 297	32 297	40 016	40 625	35 794	35 794	35 794	35 794	35 794	35 794	43 513	48 036
NG65	Cost of layer/s import	Zero Haulage	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	13 813	11 375	13 813	11 375	22 750	20 313	22 750	13 116	23 563	13 116	23 563	22 054	32 500	30 991	32 500
			TRH4	12 458	12 458	20 786	20 786	20 786	20 786	29 724	29 724	13 135	13 135	21 464	21 464	21 464	21 464	30 401	30 401	13 135	13 135	22 073	22 073	22 073	22 073	31 010	31 688
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	31 098	31 098	13 116	13 749	21 464	22 097	22 054	23 390	35 212	35 212
			ORN31	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	14 229	14 229	14 229	14 229	14 229	14 229	21 948	23 390
		Low	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	15 844	11 375	15 844	11 375	24 781	20 313	24 781	13 116	25 594	13 116	25 594	22 054	34 531	30 991	34 531
			TRH4	13 813	13 813	22 141	22 141	22 141	22 141	31 078	31 078	23 156	23 156	23 156	23 156	23 156	23 156	32 094	32 094	14 828	14 828	23 766	23 766	23 766	23 766	32 703	33 719
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	33 129	33 129	13 116	13 749	21 464	22 097	22 054	26 099	37 920	37 920
			ORN31	15 844	15 844	15 844	15 844	15 844	15 844	23 563	24 172	15 844	15 844	15 844	15 844	15 844	15 844	23 563	24 172	16 599	16 599	16 599	16 599	16 599	16 599	24 318	26 099
		Medium	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	20 313	11 375	20 313	11 375	29 250	20 313	29 250	13 116	30 063	13 116	30 063	22 054	39 000	30 991	39 000
			TRH4	16 792	16 792	25 120	25 120	25 120	25 120	34 057	34 057	18 552	18 552	26 880	26 880	26 880	26 880	35 818	35 818	18 552	18 552	27 490	27 490	27 490	27 490	36 427	38 188
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	37 598	37 598	13 116	13 749	21 464	22 097	22 054	32 057	43 879	43 879
			ORN31	20 313	20 313	20 313	20 313	20 313	20 313	28 031	28 641	20 313	20 313	20 313	20 313	20 313	20 313	28 031	28 641	21 813	21 813	21 813	21 813	21 813	21 813	29 531	32 057
		High	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	32 297	11 375	32 297	11 375	41 234	20 313	41 234	13 116	42 047	13 116	42 047	22 054	50 984	30 991	50 984
			TRH4	24 781	24 781	33 109	33 109	33 109	33 109	42 047	42 047	28 539	28 539	36 867	36 867	36 867	36 867	45 805	45 805	28 539	28 539	36 867	36 867	36 867	36 867	45 805	49 563
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	49 582	49 582	13 116	13 749	21 464	22 097	22 054	48 036	59 858	59 858
			ORN31	32 297	32 297	32 297	32 297	32 297	32 297	40 016	40 625	32 297	32 297	32 297	32 297	32 297	32 297	40 016	40 625	35 794	35 794	35 794	35 794	35 794	35 794	43 513	48 036
NG80	Cost of layer/s import	Zero Haulage	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	13 813	11 375	13 813	11 375	22 750	20 313	22 750	13 116	23 563	13 116	23 563	22 054	32 500	30 991	32 500
			TRH4	12 458	12 458	20 786	20 786	20 786	20 786	29 724	29 724	13 135	13 135	21 464	21 464	21 464	21 464	30 401	30 401	13 135	13 135	22 073	22 073	22 073	22 073	31 010	31 688
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	31 098	31 098	13 116	13 749	21 464	22 097	22 054	23 390	35 212	35 212
			ORN31	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	14 229	14 229	14 229	14 229	14 229	14 229	21 948	23 390
		Low	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	13 813	11 375	13 813	11 375	24 781	20 313	24 781	13 116	23 563	13 116	23 563	22 054	32 500	30 991	32 500
			TRH4	12 458	12 458	21 599	21 599	21 599	21 599	30 536	30 536	13 135	13 135	22 276	22 276	22 276	22 276	31 214	31 214	13 135	13 135	22 885	22 885	22 885	22 885	31 823	32 500
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	31 098	31 098	13 116	13 749	21 464	22 097	22 054	23 390	35 212	35 212
			ORN31	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	14 229	14 229	14 229	14 229	14 229	14 229	24 318	26 099
		Medium	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	13 813	11 375	13 813	11 375	29 250	20 313	29 250	13 116	23 563	13 116	23 563	22 054	32 500	30 991	32 500
			TRH4	12 458	12 458	21 599	21 599	21 599	21 599	30 536	30 536	13 135	13 135	22 276	22 276	22 276	22 276	31 214	31 214	13 135	13 135	22 885	22 885	22 885	22 885	31 823	32 500
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	31 098	31 098	13 116	13 749	21 464	22 097	22 054	23 390	35 212	35 212
			ORN31	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	14 229	14 229	14 229	14 229	14 229	14 229	21 948	23 390
		High	DCP-DN	2 438	12 188	2 438	12 188	11 375	12 188	11 375	12 188	11 375	13 813	11 375	13 813	11 375	41 234	20 313	41 234	13 116	23 563	13 116	23 563	22 054	32 500	30 991	32 500
			TRH4	12 458	12 458	21 599	21 599	21 599	21 599	30 536	30 536	22 276	22 276	22 276	22 276	22 276	22 276	31 214	31 214	13 135	13 135	22 885	22 885	22 885	22 885	31 823	32 500
			DCP-CBR	11 620	12 188	12 188	19 967	20 535	21 000	29 183	29 183	12 070	12 652	12 652	20 418	21 000	21 870	31 098	31 098	13 116	13 749	21 464	22 097	22 054	23 390	35 212	35 212
			ORN31	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	13 813	13 813	13 813	13 813	13 813	13 813	21 531	22 141	14 229	14 229	14 229	14 229	14 229	14 229	21 948	23 390

(3) Pavement Cost Ratios

Cost ratios					Cost-effectiveness DCP-DN versus other methods																							
Traffic					Low (< 0.1 MESA)								Medium (0.1 - 0.3 MESA)								High (0.3 - 1.0 MESA)							
ORN31 subgrade class					V Good (S6)	V Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S6)	Poor S5)	V Good (S6)	V Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S6)	Poor S5)	V Good (S6)	V Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S6)	Poor S5)
Subgrade					Very Good (NG25/30)		Good (NG15)		Fair (NG7)		Poor (NG3)		Very Good (NG25/30)		Good (NG15)		Fair (NG7)		Poor (NG3)		Very Good (NG25/30)		Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	5,11	1,02	8,53	1,71	1,83	1,71	2,61	2,44	1,15	0,95	1,89	1,55	1,89	0,94	1,50	1,34	1,00	0,56	1,68	0,94	1,00	0,68	1,00	0,98
				DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39	1,06	0,92	1,11	1,48	1,85	0,96	1,53	1,37	1,00	0,58	1,64	0,94	1,00	0,72	1,14	1,08
				ORN31	5,67	1,13	5,67	1,13	1,21	1,13	1,89	1,82	1,21	1,00	1,21	1,00	1,21	0,61	1,06	0,97	1,08	0,60	1,08	0,60	0,65	0,44	0,71	0,72
			Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	5,67	0,97	9,78	1,68	2,10	1,68	2,88	2,30	1,11	0,94	1,85	1,57	1,85	1,00	1,51	1,36	0,98	0,54	1,70	0,93	1,07	0,71	1,05	0,98
				DCP-CBR	5,43	1,00	5,83	1,63	1,98	1,73	2,89	2,31	1,02	0,93	1,10	1,49	1,72	1,04	1,56	1,40	1,00	0,60	1,66	0,96	1,08	0,77	1,22	1,10
				ORN31	6,50	1,11	6,50	1,11	1,39	1,11	2,19	1,82	1,18	1,00	1,18	1,00	1,18	0,64	1,12	1,04	1,10	0,60	1,10	0,60	0,69	0,45	0,78	0,77
			Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	6,89	0,90	12,53	1,63	2,68	1,63	3,47	2,11	1,04	0,91	1,81	1,59	1,81	1,10	1,54	1,41	0,95	0,51	1,73	0,93	1,19	0,75	1,14	0,98
				DCP-CBR	6,90	1,00	7,67	1,63	2,38	1,75	3,59	2,19	0,97	0,94	1,07	1,52	1,54	1,18	1,60	1,46	1,00	0,61	1,69	0,98	1,23	0,85	1,37	1,13
				ORN31	8,33	1,09	8,33	1,09	1,79	1,09	2,85	1,82	1,14	1,00	1,14	1,00	1,14	0,69	1,21	1,16	1,11	0,60	1,11	0,60	0,76	0,48	0,90	0,85
			High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	10,17	0,81	19,90	1,58	4,26	1,58	5,05	1,87	0,96	0,88	1,75	1,62	1,75	1,27	1,58	1,48	0,90	0,47	1,77	0,92	1,38	0,81	1,31	0,99
				DCP-CBR	10,83	1,00	12,58	1,62	3,43	1,77	5,49	2,04	0,90	0,96	1,04	1,55	1,32	1,41	1,66	1,56	1,00	0,63	1,73	1,02	1,46	0,96	1,65	1,17
				ORN31	13,25	1,05	13,25	1,05	2,84	1,05	4,60	1,83	1,08	1,00	1,08	1,00	1,08	0,78	1,35	1,36	1,13	0,59	1,13	0,59	0,88	0,52	1,13	0,96
	NG25/30	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	5,11	1,02	8,53	1,71	1,83	1,71	2,61	2,44	1,15	0,95	1,89	1,55	1,89	0,94	1,50	1,34	1,00	0,56	1,68	0,94	1,00	0,68	1,00	0,98
				DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39	1,06	0,92	1,11	1,48	1,85	0,96	1,53	1,37	1,00	0,58	1,64	0,94	1,00	0,72	1,14	1,08
				ORN31	5,67	1,13	5,67	1,13	1,21	1,13	1,89	1,82	1,21	1,00	1,21	1,00	1,21	0,61	1,06	0,97	1,08	0,60	1,08	0,60	0,65	0,44	0,71	0,72
			Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	5,67	0,97	9,08	1,56	1,95	1,56	2,73	2,19	1,30	0,94	2,04	1,46	2,04	0,93	1,58	1,30	0,98	0,54	1,57	0,86	0,99	0,65	0,99	0,92
				DCP-CBR	5,43	1,00	5,83	1,52	1,98	1,62	2,74	2,20	1,20	0,93	1,29	1,39	2,02	0,98	1,63	1,34	1,00	0,60	1,55	0,90	1,00	0,71	1,15	1,04
				ORN31	6,50	1,11	6,50	1,11	1,39	1,11	2,07	1,70	1,39	1,00	1,39	1,00	1,39	0,64	1,16	0,98	1,10	0,60	1,10	0,60	0,69	0,45	0,74	0,71
			Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	6,89	0,90	10,31	1,34	2,21	1,34	2,99	1,82	1,63	0,91	2,36	1,32	2,36	0,92	1,76	1,22	0,95	0,51	1,40	0,75	0,96	0,60	0,97	0,84
				DCP-CBR	6,90	1,00	7,67	1,35	2,38	1,47	3,14	1,91	1,52	0,94	1,68	1,26	2,42	1,01	1,85	1,29	1,00	0,61	1,43	0,84	1,00	0,70	1,17	0,96
				ORN31	8,33	1,09	8,33	1,09	1,79	1,09	2,46	1,53	1,79	1,00	1,79	1,00	1,79	0,69	1,38	0,98	1,11	0,60	1,11	0,60	0,76	0,48	0,79	0,70
			High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	10,17	0,81	13,58	1,08	2,91	1,08	3,70	1,37	2,51	0,88	3,24	1,14	3,24	0,89	2,26	1,11	0,90	0,47	1,17	0,61	0,91	0,53	0,93	0,71
				DCP-CBR	10,83	1,00	12,58	1,13	3,43	1,29	4,19	1,55	2,36	0,96	2,74	1,09	3,47	1,05	2,44	1,20	1,00	0,63	1,26	0,77	1,00	0,69	1,21	0,86
				ORN31	13,25	1,05	13,25	1,05	2,84	1,05	3,52	1,32	2,84	1,00	2,84	1,00	2,84	0,78	1,97	0,99	1,13	0,59	1,13	0,59	0,88	0,52	0,88	0,69
	NG45	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	5,11	1,02	8,53	1,71	1,83	1,71	2,61	2,44	1,15	0,95	1,89	1,55	1,89	0,94	1,50	1,34	1,00	0,56	1,68	0,94	1,00	0,68	1,00	0,98
				DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39	1,06	0,92	1,11	1,48	1,85	0,96	1,53	1,37	1,00	0,58	1,64	0,94	1,00	0,72	1,14	1,08
				ORN31	5,67	1,13	5,67	1,13	1,21	1,13	1,89	1,82	1,21	1,00	1,21	1,00	1,21	0,61	1,06	0,97	1,08	0,60	1,08	0,60	0,65	0,44	0,71	0,72
			Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	5,67	0,97	9,08	1,56	1,95	1,56	2,73	2,19	1,30	0,94	2,04	1,46	2,04	0,93	1,58	1,30	0,98	0,54	1,57	0,86	0,99	0,65	0,99	0,92
				DCP-CBR	4,77	0,86	5,00	1,40	1,81	1,62	2,74	2,20	1,20	0,93	1,29	1,39	2,02	0,98	1,63	1,34	1,00	0,60	1,55	0,90	1,00	0,71	1,15	1,04
				ORN31	6,50	1,11	6,50	1,11	1,39	1,11	2,07	1,70	1,39	1,00	1,39	1,00	1,39	0,64	1,16	0,98	1,10	0,60	1,10	0,60	0,69	0,45	0,74	0,71
			Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	6,89	0,90	10,31	1,34	2,21	1,34	2,99	1,82	1,63	0,91	2,36	1,32	2,36	0,92	1,76	1,22	0,95	0,51	1,40	0,75	0,96	0,60	0,97	0,84
				DCP-CBR	4,77	0,65	5,00	1,07	1,81	1,47	3,14	1,91	1,52	0,94	1,68	1,26	2,42	1,01	1,85	1,29	1,00	0,61	1,43	0,84	1,00	0,70	1,17	0,96
				ORN31	8,33	1,09	8,33	1,09	1,79	1,09	2,46	1,53	1,79	1,00	1,79	1,00	1,79	0,69	1,38	0,98	1,11	0,60	1,11	0,60	0,76	0,48	0,79	0,70
			High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
				TRH4	10,17	0,81	13,58	1,08	2,91	1,08	3,70	1,37	2,51	0,88	3,24	1,14	3,24	0,89	2,26	1,11	0,90	0,47	1,17	0,61	0,91	0,53	0,93	0,71
				DCP-CBR	4,77	0,40	5,00	0,65	1,81	1,29	4,19	1,55	2,36	0,96	2,74	1,09	3,47	1,05	2,44	1,20	1,00	0,63	1,26	0,77	1,00	0,69	1,21	0,86
				ORN31	13,25	1,05	13,25	1,05	2,84	1,05	3,52	1,32	2,84	1,00	2,84	1,00	2,84	0,78	1,97	0,99	1,13	0,59	1,13	0,59	0,88	0,52	0,88	0,69

(4) Pavement Cost Ratios (Cont'd)

Cost ratios				Cost-effectiveness DCP-DN versus other methods							
Traffic				Low (< 0.1 MESA)							
ORN31 subgrade class				V Good (S6)	V Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S6)	Poor S5)
Subgrade				Very Good (NG25/30)		Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate				Dry - Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
NG55	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	5,11	1,02	8,53	1,71	1,83	1,71	2,61	2,44
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39
			ORN31	5,67	1,13	5,67	1,13	1,21	1,13	1,89	1,82
		Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	5,67	1,13	9,08	1,82	1,95	1,82	2,73	2,55
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,74	2,56
			ORN31	6,50	1,30	6,50	1,30	1,39	1,30	2,07	1,98
		Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	6,89	1,38	10,31	2,06	2,21	2,06	2,99	2,79
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	3,14	2,93
			ORN31	8,33	1,67	8,33	1,67	1,79	1,67	2,46	2,35
		High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	10,17	2,03	13,58	2,72	2,91	2,72	3,70	3,45
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	4,19	3,91
			ORN31	13,25	2,65	13,25	2,65	2,84	2,65	3,52	3,33
NG65	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	5,11	1,02	8,53	1,71	1,83	1,71	2,61	2,44
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39
			ORN31	5,67	1,13	5,67	1,13	1,21	1,13	1,89	1,82
		Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	5,67	1,13	9,08	1,82	1,95	1,82	2,73	2,55
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39
			ORN31	6,50	1,30	6,50	1,30	1,39	1,30	2,07	1,98
		Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	6,89	1,38	10,31	2,06	2,21	2,06	2,99	2,79
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39
			ORN31	8,33	1,67	8,33	1,67	1,79	1,67	2,46	2,35
		High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	10,17	2,03	13,58	2,72	2,91	2,72	3,70	3,45
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39
			ORN31	13,25	2,65	13,25	2,65	2,84	2,65	3,52	3,33
NG80	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	5,11	1,02	8,53	1,71	1,83	1,71	2,61	2,44
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39
			ORN31	5,67	1,13	5,67	1,13	1,21	1,13	1,89	1,82
		Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	5,11	1,02	8,86	1,77	1,90	1,77	2,68	2,51
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39
			ORN31	5,67	1,13	5,67	1,13	1,21	1,13	1,89	1,82
		Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	5,11	1,02	8,86	1,77	1,90	1,77	2,68	2,51
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39
			ORN31	5,67	1,13	5,67	1,13	1,21	1,13	1,89	1,82
		High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	5,11	1,02	8,86	1,77	1,90	1,77	2,68	2,51
			DCP-CBR	4,77	1,00	5,00	1,64	1,81	1,72	2,57	2,39
			ORN31	5,67	1,13	5,67	1,13	1,21	1,13	1,89	1,82

Traffic				Medium (0.1 - 0.3 MESA)							
ORN31 subgrade class				V Good (S6)	V Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S6)	Poor S5)
Subgrade				Very Good (NG25/30)		Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate				Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
NG55	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,15	0,95	1,89	1,55	1,89	0,94	1,50	1,34
			DCP-CBR	1,06	0,92	1,11	1,48	1,85	0,96	1,53	1,37
			ORN31	1,21	1,00	1,21	1,00	1,21	0,61	1,06	0,97
		Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,30	0,94	2,04	1,46	2,04	0,93	1,58	1,30
			DCP-CBR	1,06	0,80	1,11	1,29	1,85	0,98	1,63	1,34
			ORN31	1,39	1,00	1,39	1,00	1,39	0,64	1,16	0,98
		Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,63	0,91	2,36	1,32	2,36	0,92	1,76	1,22
			DCP-CBR	1,06	0,62	1,11	1,01	1,85	1,01	1,85	1,29
			ORN31	1,79	1,00	1,79	1,00	1,79	0,69	1,38	0,98
		High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	2,51	0,88	3,24	1,14	3,24	0,89	2,26	1,11
			DCP-CBR	1,06	0,39	1,11	0,63	1,85	1,05	2,44	1,20
			ORN31	2,84	1,00	2,84	1,00	2,84	0,78	1,97	0,99
NG65	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,15	0,95	1,89	1,55	1,89	0,94	1,50	1,34
			DCP-CBR	1,06	0,92	1,11	1,48	1,85	0,96	1,53	1,37
			ORN31	1,21	1,00	1,21	1,00	1,21	0,61	1,06	0,97
		Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	2,04	1,46	2,04	1,46	2,04	0,93	1,58	1,30
			DCP-CBR	1,06	0,80	1,11	1,29	1,85	0,88	1,63	1,34
			ORN31	1,39	1,00	1,39	1,00	1,39	0,64	1,16	0,98
		Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,63	0,91	2,36	1,32	2,36	0,92	1,76	1,22
			DCP-CBR	1,06	0,62	1,11	1,01	1,85	0,75	1,85	1,29
			ORN31	1,79	1,00	1,79	1,00	1,79	0,69	1,38	0,98
		High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	2,51	0,88	3,24	1,14	3,24	0,89	2,26	1,11
			DCP-CBR	1,06	0,39	1,11	0,63	1,85	0,53	2,44	1,20
			ORN31	2,84	1,00	2,84	1,00	2,84	0,78	1,97	0,99
NG80	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,15	0,95	1,89	1,55	1,89	0,94	1,50	1,34
			DCP-CBR	1,06	0,92	1,11	1,48	1,85	0,96	1,53	1,37
			ORN31	1,21	1,00	1,21	1,00	1,21	0,61	1,06	0,97
		Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,15	0,95	1,96	1,61	1,96	0,90	1,54	1,26
			DCP-CBR	1,06	0,92	1,11	1,48	1,85	0,88	1,53	1,25
			ORN31	1,21	1,00	1,21	1,00	1,21	0,56	1,06	0,89
		Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,15	0,95	1,96	1,61	1,96	0,76	1,54	1,07
			DCP-CBR	1,06	0,92	1,11	1,48	1,85	0,75	1,53	1,06
			ORN31	1,21	1,00	1,21	1,00	1,21	0,47	1,06	0,76
		High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,96	1,61	1,96	1,61	1,96	0,54	1,54	0,76
			DCP-CBR	1,06	0,92	1,11	1,48	1,85	0,53	1,53	0,75
			ORN31	1,21	1,00	1,21	1,00	1,21	0,33	1,06	0,54

Traffic				High (0.3 - 1.0 MESA)							
ORN31 subgrade class				V Good (S6)	V Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S6)	Poor S5)
Subgrade				Very Good (NG25/30)		Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate				Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet	Dry -Moderate	Wet
NG55	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,00	0,56	1,68	0,94	1,00	0,68	1,00	0,98
			DCP-CBR	1,00	0,58	1,64	0,94	1,00	0,72	1,14	1,08
			ORN31	1,08	0,60	1,08	0,60	0,65	0,44	0,71	0,72
		Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	0,98	0,58	1,57	0,93	0,99	0,69	0,99	0,98
			DCP-CBR	1,00	0,64	1,55	0,97	1,00	0,76	1,15	1,10
			ORN31	1,10	0,65	1,10	0,65	0,69	0,48	0,74	0,76
		Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	0,95	0,62	1,40	0,91	0,96	0,70	0,97	0,98
			DCP-CBR	1,00	0,75	1,43	1,02	1,00	0,82	1,17	1,13
			ORN31	1,11	0,73	1,11	0,73	0,76	0,56	0,79	0,82
		High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	0,90	0,68	1,17	0,88	0,91	0,72	0,93	0,97
			DCP-CBR	1,00	0,91	1,26	1,11	1,00	0,94	1,21	1,17
			ORN31	1,13	0,85	1,13	0,85	0,88	0,70	0,88	0,94
NG65	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,00	0,56	1,68	0,94	1,00	0,68	1,00	0,98
			DCP-CBR	1,00	0,58	1,64	0,94	1,00	0,72	1,14	1,08
			ORN31	1,08	0,60	1,08	0,60	0,65	0,44	0,71	0,72
		Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,13	0,58	1,81	0,93	1,08	0,69	1,06	0,98
			DCP-CBR	1,00	0,54	1,64	0,86	1,00	0,76	1,22	1,10
			ORN31	1,27	0,65	1,27	0,65	0,75	0,48	0,78	0,76
		Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,41	0,62	2,10	0,91	1,25	0,70	1,18	0,98
			DCP-CBR	1,00	0,46	1,64	0,74	1,00	0,82	1,42	1,13
			ORN31	1,66	0,73	1,66	0,73	0,99	0,56	0,95	0,82
		High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	2,18	0,68	2,81	0,88	1,67	0,72	1,48	0,97
			DCP-CBR	1,00	0,33	1,64	0,53	1,00	0,94	1,93	1,17
			ORN31	2,73	0,85	2,73	0,85	1,62	0,70	1,40	0,94
NG80	Cost of layer/s import	Zero Haulage	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,00	0,56	1,68	0,94	1,00	0,68	1,00	0,98
			DCP-CBR	1,00	0,58	1,64	0,94	1,00	0,72	1,14	1,08
			ORN31	1,08	0,60	1,08	0,60	0,65	0,44	0,71	0,72
		Low	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,00	0,56	1,74	0,97	1,04	0,70	1,03	1,00
			DCP-CBR	1,00	0,58	1,64	0,94	1,00	0,72	1,14	1,08
			ORN31	1,08	0,60	1,08	0,60	0,65	0,44	0,78	0,80
		Medium	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,00	0,56	1,74	0,97	1,04	0,70	1,03	1,00
			DCP-CBR	1,00	0,58	1,64	0,94	1,00	0,72	1,14	1,08
			ORN31	1,08	0,60	1,08	0,60	0,65	0,44	0,71	0,72
		High	DCP-DN	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
			TRH4	1,00	0,56	1,74	0,97	1,04	0,70	1,03	1,00
			DCP-CBR	1,00	0,58	1,64	0,94	1,00	0,72	1,14	1,08
			ORN31	1,08	0,60	1,08	0,60	0,65	0,44	0,71	0,72

(5) Project Costs

Summary of Project costs					USD per km of 6.5m wide																							
Traffic					Low (< 0.1 MESA)								Medium (0.1 - 0.3 MESA)								High (0.3 - 1.0 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials / Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	123,942	120,705	123,942	120,705	135,814	132,576	135,814	123,017	136,893	123,017	136,893	134,889	148,764	146,760	148,764
				TRH4	122,144	122,144	133,205	133,205	133,205	133,205	145,077	145,077	123,043	123,043	134,105	134,105	134,105	134,105	145,976	145,976	123,043	123,043	134,914	134,914	134,914	134,914	146,785	147,685
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	146,902	146,902	123,017	123,858	134,105	134,946	134,889	136,664	152,366	152,366
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	124,496	124,496	124,496	124,496	124,496	124,496	134,748	136,664
			Low	DCP-DN	108,833	124,482	108,833	124,482	120,705	124,482	120,705	124,482	123,403	126,640	123,403	126,640	123,403	138,512	135,274	138,512	125,715	142,289	125,715	142,289	137,587	154,160	149,438	154,160
				TRH4	123,942	123,942	137,253	137,253	137,253	137,253	149,124	149,124	125,291	125,291	138,602	138,602	138,602	138,602	150,473	150,473	125,291	125,291	139,861	139,861	139,861	139,861	151,732	153,081
				DCP-CBR	123,188	124,482	124,482	136,434	135,570	138,345	149,214	149,214	123,786	125,099	125,099	137,083	136,187	139,951	151,758	151,758	125,715	127,456	138,962	140,702	140,285	142,959	159,111	159,111
				ORN31	126,640	126,640	126,640	126,640	126,640	126,640	138,691	139,951	126,640	126,640	126,640	126,640	126,640	126,640	138,691	139,951	127,643	127,643	127,643	127,643	127,643	127,643	139,695	142,959
			Medium	DCP-DN	108,833	130,418	108,833	130,418	120,705	130,418	120,705	130,418	129,338	132,576	129,338	132,576	129,338	144,447	141,210	144,447	131,651	154,160	131,651	154,160	143,522	166,081	155,393	166,081
				TRH4	127,899	127,899	146,156	146,156	146,156	146,156	158,027	158,027	130,238	130,238	148,494	148,494	148,494	148,494	160,365	160,365	130,238	130,238	150,743	150,743	150,743	150,743	162,614	164,952
				DCP-CBR	127,937	130,418	130,418	145,931	141,506	149,029	159,898	159,898	128,535	131,034	131,034	146,529	142,122	151,624	162,442	162,442	131,651	135,370	149,646	153,365	152,156	156,809	173,950	173,950
				ORN31	132,576	132,576	132,576	132,576	132,576	132,576	148,584	150,832	132,576	132,576	132,576	132,576	132,576	132,576	148,584	150,832	134,568	134,568	134,568	134,568	134,568	134,568	150,577	156,809
			High	DCP-DN	108,833	146,336	108,833	146,336	120,705	146,336	120,705	146,336	145,257	148,494	145,257	148,494	145,257	160,365	157,128	160,365	147,569	185,997	147,569	185,997	159,440	197,868	171,312	197,868
				TRH4	138,512	138,512	170,033	170,033	170,033	170,033	181,905	181,905	143,503	143,503	175,025	175,025	175,025	175,025	186,896	186,896	143,503	143,503	179,926	179,926	179,926	179,926	191,797	196,789
				DCP-CBR	140,671	146,336	146,336	171,401	157,424	177,682	188,551	188,551	141,269	146,952	146,952	171,999	158,041	182,980	191,095	191,095	147,569	156,594	178,299	187,324	188,992	193,952	213,746	213,746
				ORN31	148,494	148,494	148,494	148,494	148,494	148,494	175,115	180,016	148,494	148,494	148,494	148,494	148,494	148,494	175,115	180,016	153,140	153,140	153,140	153,140	153,140	153,140	179,760	193,952
	NG25/30	Cost of layer/s import	Zero Haulage	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	123,942	120,705	123,942	120,705	135,814	132,576	135,814	123,017	136,893	123,017	136,893	134,889	148,764	146,760	148,764
				TRH4	122,144	122,144	133,205	133,205	133,205	133,205	145,077	145,077	123,043	123,043	134,105	134,105	134,105	134,105	145,976	145,976	123,043	123,043	134,914	134,914	134,914	134,914	146,785	147,685
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	146,902	146,902	123,017	123,858	134,105	134,946	134,889	136,664	152,366	152,366
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	124,496	124,496	124,496	124,496	124,496	124,496	134,748	136,664
			Low	DCP-DN	108,833	124,482	108,833	124,482	120,705	124,482	120,705	124,482	120,705	126,640	120,705	126,640	120,705	138,512	132,576	138,512	125,715	142,289	125,715	142,289	137,587	154,160	149,438	154,160
				TRH4	123,942	123,942	135,004	135,004	135,004	135,004	146,875	146,875	125,291	125,291	136,353	136,353	136,353	136,353	148,224	148,224	125,291	125,291	137,163	137,163	137,163	137,163	149,034	150,383
				DCP-CBR	123,188	124,482	124,482	134,276	135,570	136,187	147,056	147,056	123,786	125,099	125,099	134,874	136,187	137,793	149,600	149,600	125,715	127,456	136,808	138,544	137,587	140,261	155,964	155,964
				ORN31	126,640	126,640	126,640	126,640	126,640	126,640	136,893	137,702	126,640	126,640	126,640	126,640	126,640	126,640	136,893	137,702	127,643	127,643	127,643	127,643	127,643	127,643	137,896	140,261
			Medium	DCP-DN	108,833	130,418	108,833	130,418	120,705	130,418	120,705	130,418	120,705	132,576	120,705	132,576	120,705	144,447	132,576	144,447	131,651	154,160	131,651	154,160	143,522	166,081	155,393	166,081
				TRH4	127,899	127,899	138,961	138,961	138,961	138,961	150,832	150,832	130,238	130,238	141,300	141,300	141,300	141,300	153,171	153,171	130,238	130,238	142,109	142,109	142,109	142,109	153,980	156,318
				DCP-CBR	127,937	130,418	130,418	139,025	141,506	142,122	152,991	152,991	128,535	131,034	131,034	139,623	142,122	144,718	155,535	155,535	131,651	135,370	142,739	146,458	143,522	148,175	163,878	163,878
				ORN31	132,576	132,576	132,576	132,576	132,576	132,576	142,828	143,638	132,576	132,576	132,576	132,576	132,576	132,576	142,828	143,638	134,568	134,568	134,568	134,568	134,568	134,568	144,821	148,175
			High	DCP-DN	108,833	146,336	108,833	146,336	120,705	146,336	120,705	146,336	120,705	148,494	120,705	148,494	120,705	160,365	132,576	160,365	147,569	185,997	147,569	185,997	159,440	197,868	171,312	197,868
				TRH4	138,512	138,512	149,573	149,573	149,573	149,573	161,445	161,445	143,503	143,503	154,565	154,565	154,565	154,565	166,436	166,436	143,503	143,503	154,565	154,565	154,565	154,565	166,436	171,427
				DCP-CBR	140,671	146,336	146,336	151,759	157,424	158,041	168,910	168,910	141,269	146,952	146,952	152,357	158,041	163,289	171,453	171,453	147,569	156,594	158,657	167,682	159,440	169,400	185,102	185,102
				ORN31	148,494	148,494	148,494	148,494	148,494	148,494	158,747	159,556	148,494	148,494	148,494	148,494	148,494	148,494	158,747	159,556	153,140	153,140	153,140	153,140	153,140	153,140	163,392	169,400
	NG45	Cost of layer/s import	Zero Haulage	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	123,942	120,705	123,942	120,705	135,814	132,576	135,814	123,017	136,893	123,017	136,893	134,889	148,764	146,760	148,764
				TRH4	122,144	122,144	133,205	133,205	133,205	133,205	145,077	145,077	123,043	123,043	134,105	134,105	134,105	134,105	145,976	145,976	123,043	123,043	134,914	134,914	134,914	134,914	146,785	147,685
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	146,902	146,902	123,017	123,858	134,105	134,946	134,889	136,664	152,366	152,366
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	124,496	124,496	124,496	124,496	124,496	124,496	134,748	136,664
			Low	DCP-DN	108,833	124,482	108,833	124,482	120,705	124,482	120,705	124,482	120,705	126,640	120,705	126,640	120,705	138,512	132,576	138,512	125,715	142,289	125,715	142,289	137,587	154,160	149,438	154,160
				TRH4	123,942	123,942	135,004	135,004	135,004	135,004	146,875	146,875	125,291	125,291	136,353	136,353	136,353	136,353	148,224	148,224	125,291	125,291	137,163	137,163	137,163	137,163	149,034	150,383
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	136,187	147,056	147,056	123,786	125,099	125,099	134,874	136,187	137,793	149,600	149,600	125,715	127,456	136,808	138,544	137,587	140,261	155,964	155,964
				ORN31	126,640	126,640	126,640	126,640	126,640	126,640	136,893	137,702	126,640	126,640	126,640	126,640	126,640	126,640	136,893	137,702	127,643	127,643	127,643	127,643	127,643	127,643	137,896	140,261
			Medium	DCP-DN	108,833	130,418	108,833	130,418	120,705	130,418	120,705	130,418	120,705	132,576	120,705	132,576	120,705	144,447	132,576	144,447	131,651	154,160	131,651	154,160	143,522	166,081	155,393	166,081
				TRH4	127,899	127,899	138,961	138,961	138,961	138,961	150,832	150,832	130,238	130,238	141,300	141,300	141,300	141,300	153,171	153,171	130,238	130,238	142,109	142,109	142,109	142,109	153,980	156,318
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	142,122	152,991	152,991	128,535	131,034	131,034	139,623	142,122	144,718	155,535	155,535	131,651	135,370	142,739	146,458	143,522	148,175	163,878	163,878
				ORN31	132,576	132,576	132,576	132,576	132,576	132,576	142,828	143,638	132,576	132,576	132,576	132,576	132,576	132,576	142,828	143,638	134,568	134,568	134,568	134,568	134,568	134,568	144,821	148,175
			High	DCP-DN	108,833	146,336	108,833	146,336	120,705	146,336	120,705	146,336	120,705	148,494	120,705	148,494	120,705	160,365	132,576	160,365	147,569	185,997	147,569	185,997	159,440	197,868	171,312	197,868
				TRH4	138,512	138,512	149,573	149,573	149,573	149,573	161,445	161,445	143,503	143,503	154,565	154,565	154,565	154,565	166,436	166,436	143,503	143,503	154,565	154,565	154,565	154,565	166,436	171,427
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	158,041	168,910	168,910	141,269	146,952	146,952	152,357	158,041	163,289	171,453	171,453	147,569	156,594	158,657	167,682	159,440	169,400	185,102	185,102
				ORN31	148,494	148,494	148,494	148,494	148,494	148,494	158,747	159,556	148,494	148,494	148,494	148,494	148,494	148,494	158,747	159,556	153,140	153,140	153,140	153,140	153,140	153,140	163,392	169,400

(6) Project Costs (Cont'd)

Available materials/ Free haul	NG55	Cost of layer/s import	Zero Haulage	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	123,942	120,705	123,942	120,705	135,814	132,576	135,814	123,017	136,893	123,017	136,893	134,889	148,764	146,760	148,764
				TRH4	122,144	122,144	133,205	133,205	133,205	133,205	145,077	145,077	123,043	123,043	134,105	134,105	134,105	134,105	145,976	145,976	123,043	123,043	134,914	134,914	134,914	134,914	146,785	147,685
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	146,902	146,902	123,017	123,858	134,105	134,946	134,889	136,664	152,366	152,366
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	124,496	124,496	124,496	124,496	124,496	124,496	134,748	136,664
			Low	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	126,640	120,705	126,640	120,705	138,512	132,576	138,512	125,715	139,591	125,715	139,591	137,587	151,462	149,438	151,462
				TRH4	123,942	123,942	135,004	135,004	135,004	135,004	146,875	146,875	125,291	125,291	136,353	136,353	136,353	136,353	148,224	148,224	125,291	125,291	137,163	137,163	137,163	137,163	149,034	150,383
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	147,056	147,056	121,628	122,401	122,401	132,716	133,489	137,793	149,600	149,600	125,715	127,456	136,808	138,544	137,587	140,261	155,964	155,964
				ORN31	126,640	126,640	126,640	126,640	126,640	126,640	136,893	137,702	126,640	126,640	126,640	126,640	126,640	126,640	136,893	137,702	127,643	127,643	127,643	127,643	127,643	127,643	137,896	140,261
			Medium	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	132,576	120,705	132,576	120,705	144,447	132,576	144,447	131,651	145,526	131,651	145,526	143,522	157,398	155,393	157,398
				TRH4	127,899	127,899	138,961	138,961	138,961	138,961	150,832	150,832	130,238	130,238	141,300	141,300	141,300	141,300	153,171	153,171	130,238	130,238	142,109	142,109	142,109	142,109	153,980	156,318
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	152,991	152,991	121,628	122,401	122,401	132,716	133,489	144,718	155,535	155,535	131,651	135,370	142,739	146,458	143,522	148,175	163,878	163,878
				ORN31	132,576	132,576	132,576	132,576	132,576	132,576	142,828	143,638	132,576	132,576	132,576	132,576	132,576	132,576	142,828	143,638	134,568	134,568	134,568	134,568	134,568	134,568	144,821	148,175
			High	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	148,494	120,705	148,494	120,705	160,365	132,576	160,365	147,569	161,445	147,569	161,445	159,440	173,316	171,312	173,316
				TRH4	138,512	138,512	149,573	149,573	149,573	149,573	161,445	161,445	143,503	143,503	154,565	154,565	154,565	154,565	166,436	166,436	143,503	143,503	154,565	154,565	154,565	154,565	166,436	171,427
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	168,910	168,910	121,628	122,401	122,401	132,716	133,489	163,289	171,453	171,453	147,569	156,594	158,657	167,682	159,440	169,400	185,102	185,102
				ORN31	148,494	148,494	148,494	148,494	148,494	148,494	158,747	159,556	148,494	148,494	148,494	148,494	148,494	148,494	158,747	159,556	153,140	153,140	153,140	153,140	153,140	153,140	163,392	169,400
	NG65	Cost of layer/s import	Zero Haulage	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	123,942	120,705	123,942	120,705	135,814	132,576	135,814	123,017	136,893	123,017	136,893	134,889	148,764	146,760	148,764
				TRH4	122,144	122,144	133,205	133,205	133,205	133,205	145,077	145,077	123,043	123,043	134,105	134,105	134,105	134,105	145,976	145,976	123,043	123,043	134,914	134,914	134,914	134,914	146,785	147,685
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	146,902	146,902	123,017	123,858	134,105	134,946	134,889	136,664	152,366	152,366
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	124,496	124,496	124,496	124,496	124,496	124,496	134,748	136,664
			Low	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	126,640	120,705	126,640	120,705	138,512	132,576	138,512	123,017	139,591	123,017	139,591	134,889	151,462	146,760	151,462
				TRH4	123,942	123,942	135,004	135,004	135,004	135,004	146,875	146,875	136,353	136,353	136,353	136,353	136,353	136,353	148,224	148,224	125,291	125,291	137,163	137,163	137,163	137,163	149,034	150,383
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	149,600	149,600	123,017	123,858	134,105	134,946	134,889	140,261	155,964	155,964
				ORN31	126,640	126,640	126,640	126,640	126,640	126,640	136,893	137,702	126,640	126,640	126,640	126,640	126,640	126,640	136,893	137,702	127,643	127,643	127,643	127,643	127,643	127,643	137,896	140,261
			Medium	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	132,576	120,705	132,576	120,705	144,447	132,576	144,447	123,017	145,526	123,017	145,526	134,889	157,398	146,760	157,398
				TRH4	127,899	127,899	138,961	138,961	138,961	138,961	150,832	150,832	130,238	130,238	141,300	141,300	141,300	141,300	153,171	153,171	130,238	130,238	142,109	142,109	142,109	142,109	153,980	156,318
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	155,535	155,535	123,017	123,858	134,105	134,946	134,889	148,175	163,878	163,878
				ORN31	132,576	132,576	132,576	132,576	132,576	132,576	142,828	143,638	132,576	132,576	132,576	132,576	132,576	132,576	142,828	143,638	134,568	134,568	134,568	134,568	134,568	134,568	144,821	148,175
			High	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	148,494	120,705	148,494	120,705	160,365	132,576	160,365	123,017	161,445	123,017	161,445	134,889	173,316	146,760	173,316
				TRH4	138,512	138,512	149,573	149,573	149,573	149,573	161,445	161,445	143,503	143,503	154,565	154,565	154,565	154,565	166,436	166,436	143,503	143,503	154,565	154,565	154,565	154,565	166,436	171,427
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	171,453	171,453	123,017	123,858	134,105	134,946	134,889	169,400	185,102	185,102
				ORN31	148,494	148,494	148,494	148,494	148,494	148,494	158,747	159,556	148,494	148,494	148,494	148,494	148,494	148,494	158,747	159,556	153,140	153,140	153,140	153,140	153,140	153,140	163,392	169,400
	NG80	Cost of layer/s import	Zero Haulage	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	123,942	120,705	123,942	120,705	135,814	132,576	135,814	123,017	136,893	123,017	136,893	134,889	148,764	146,760	148,764
				TRH4	122,144	122,144	133,205	133,205	133,205	133,205	145,077	145,077	123,043	123,043	134,105	134,105	134,105	134,105	145,976	145,976	123,043	123,043	134,914	134,914	134,914	134,914	146,785	147,685
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	146,902	146,902	123,017	123,858	134,105	134,946	134,889	136,664	152,366	152,366
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	124,496	124,496	124,496	124,496	124,496	124,496	134,748	136,664
			Low	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	123,942	120,705	123,942	120,705	138,512	132,576	138,512	123,017	136,893	123,017	136,893	134,889	148,764	146,760	148,764
				TRH4	122,144	122,144	134,285	134,285	134,285	134,285	146,156	146,156	123,043	123,043	135,184	135,184	135,184	135,184	147,055	147,055	123,043	123,043	135,993	135,993	135,993	135,993	147,865	148,764
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	146,902	146,902	123,017	123,858	134,105	134,946	134,889	136,664	152,366	152,366
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	124,496	124,496	124,496	124,496	124,496	124,496	137,896	140,261
			Medium	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	123,942	120,705	123,942	120,705	144,447	132,576	144,447	123,017	136,893	123,017	136,893	134,889	148,764	146,760	148,764
				TRH4	122,144	122,144	134,285	134,285	134,285	134,285	146,156	146,156	123,043	123,043	135,184	135,184	135,184	135,184	147,055	147,055	123,043	123,043	135,993	135,993	135,993	135,993	147,865	148,764
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	146,902	146,902	123,017	123,858	134,105	134,946	134,889	136,664	152,366	152,366
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	124,496	124,496	124,496	124,496	124,496	124,496	134,748	136,664
			High	DCP-DN	108,833	121,784	108,833	121,784	120,705	121,784	120,705	121,784	120,705	123,942	120,705	123,942	120,705	160,365	132,576	160,365	123,017	136,893	123,017	136,893	134,889	148,764	146,760	148,764
				TRH4	122,144	122,144	134,285	134,285	134,285	134,285	146,156	146,156	135,184	135,184	135,184	135,184	135,184	135,184	147,055	147,055	123,043	123,043	135,993	135,993	135,993	135,993	147,865	148,764
				DCP-CBR	121,030	121,784	121,784	132,118	132,872	133,489	144,358	144,358	121,628	122,401	122,401	132,716	133,489	134,645	146,902	146,902	123,017	123,858	134,105	134,946	134,889	136,664	152,366	152,366
				ORN31	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	123,942	123,942	123,942	123,942	123,942	123,942	134,195	135,004	124,496	124,496	124,496	124,496	124,496	124,496	134,748	136,664

(7) Project Costs Ratios

Project Cost Ratios					Based on USD per km of 6.5m wide																							
Traffic					Low (< 0.1 MESA)								Medium (0.1 - 0.3 MESA)								High (0.3 - 1.0 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials/ Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.22	1.09	1.10	1.09	1.20	1.19	1.02	0.99	1.11	1.08	1.11	0.99	1.10	1.07	1.00	0.90	1.10	0.99	1.00	0.91	1.00	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.99	1.01	1.07	1.11	0.99	1.11	1.08	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11	1.03	1.00	1.03	1.00	1.03	0.91	1.01	0.99	1.01	0.91	1.01	0.91	0.92	0.84	0.92	0.92
			Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.14	1.00	1.26	1.10	1.14	1.10	1.24	1.20	1.02	0.99	1.12	1.09	1.12	1.00	1.11	1.09	1.00	0.88	1.11	0.98	1.02	0.91	1.02	0.99
				DCP-CBR	1.13	1.00	1.14	1.10	1.12	1.11	1.24	1.20	1.00	0.99	1.01	1.08	1.10	1.01	1.12	1.10	1.00	0.90	1.11	0.99	1.02	0.93	1.06	1.03
				ORN31	1.16	1.02	1.16	1.02	1.05	1.02	1.15	1.12	1.03	1.00	1.03	1.00	1.03	0.91	1.03	1.01	1.02	0.90	1.02	0.90	0.93	0.83	0.93	0.93
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.18	0.98	1.34	1.12	1.21	1.12	1.31	1.21	1.01	0.98	1.15	1.12	1.15	1.03	1.14	1.11	0.99	0.84	1.15	0.98	1.05	0.91	1.05	0.99
				DCP-CBR	1.18	1.00	1.20	1.12	1.17	1.14	1.32	1.23	0.99	0.99	1.01	1.11	1.10	1.05	1.15	1.12	1.00	0.88	1.14	0.99	1.06	0.94	1.12	1.05
				ORN31	1.22	1.02	1.22	1.02	1.10	1.02	1.23	1.16	1.03	1.00	1.03	1.00	1.03	0.92	1.05	1.04	1.02	0.87	1.02	0.87	0.94	0.81	0.97	0.94
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.27	0.95	1.56	1.16	1.41	1.16	1.51	1.24	0.99	0.97	1.20	1.18	1.20	1.09	1.19	1.17	0.97	0.77	1.22	0.97	1.13	0.91	1.12	0.99
				DCP-CBR	1.29	1.00	1.34	1.17	1.30	1.21	1.56	1.29	0.97	0.99	1.01	1.16	1.09	1.14	1.22	1.19	1.00	0.84	1.21	1.01	1.15	0.98	1.25	1.08
				ORN31	1.36	1.01	1.36	1.01	1.23	1.01	1.45	1.23	1.02	1.00	1.02	1.00	1.02	0.93	1.11	1.12	1.04	0.82	1.04	0.82	0.96	0.77	1.05	0.98
	NG25/30	Cost of layer/s import	Zero Haulage	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.22	1.09	1.10	1.09	1.20	1.19	1.02	0.99	1.11	1.08	1.11	0.99	1.10	1.07	1.00	0.90	1.10	0.99	1.00	0.91	1.00	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.99	1.01	1.07	1.11	0.99	1.11	1.08	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11	1.03	1.00	1.03	1.00	1.03	0.91	1.01	0.99	1.01	0.91	1.01	0.91	0.92	0.84	0.92	0.92
			Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.14	1.00	1.24	1.08	1.12	1.08	1.22	1.18	1.04	0.99	1.13	1.08	1.13	0.98	1.12	1.07	1.00	0.88	1.09	0.96	1.00	0.89	1.00	0.98
				DCP-CBR	1.13	1.00	1.14	1.08	1.12	1.09	1.22	1.18	1.03	0.99	1.04	1.07	1.13	0.99	1.13	1.08	1.00	0.90	1.09	0.97	1.00	0.91	1.04	1.01
				ORN31	1.16	1.02	1.16	1.02	1.05	1.02	1.13	1.11	1.05	1.00	1.05	1.00	1.05	0.91	1.03	0.99	1.02	0.90	1.02	0.90	0.93	0.83	0.92	0.91
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.18	0.98	1.28	1.07	1.15	1.07	1.25	1.16	1.08	0.98	1.17	1.07	1.17	0.98	1.16	1.06	0.99	0.84	1.08	0.92	0.99	0.86	0.99	0.94
				DCP-CBR	1.18	1.00	1.20	1.07	1.17	1.09	1.27	1.17	1.06	0.99	1.09	1.05	1.18	1.00	1.17	1.08	1.00	0.88	1.08	0.95	1.00	0.89	1.05	0.99
				ORN31	1.22	1.02	1.22	1.02	1.10	1.02	1.18	1.10	1.10	1.00	1.10	1.00	1.10	0.92	1.08	0.99	1.02	0.87	1.02	0.87	0.94	0.81	0.93	0.89
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.27	0.95	1.37	1.02	1.24	1.02	1.34	1.10	1.19	0.97	1.28	1.04	1.28	0.96	1.26	1.04	0.97	0.77	1.05	0.83	0.97	0.78	0.97	0.87
				DCP-CBR	1.29	1.00	1.34	1.04	1.30	1.08	1.40	1.15	1.17	0.99	1.22	1.03	1.31	1.02	1.29	1.07	1.00	0.84	1.08	0.90	1.00	0.86	1.08	0.94
				ORN31	1.36	1.01	1.36	1.01	1.23	1.01	1.32	1.09	1.23	1.00	1.23	1.00	1.23	0.93	1.20	0.99	1.04	0.82	1.04	0.82	0.96	0.77	0.95	0.86
	NG45	Cost of layer/s import	Zero Haulage	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.22	1.09	1.10	1.09	1.20	1.19	1.02	0.99	1.11	1.08	1.11	0.99	1.10	1.07	1.00	0.90	1.10	0.99	1.00	0.91	1.00	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.99	1.01	1.07	1.11	0.99	1.11	1.08	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11	1.03	1.00	1.03	1.00	1.03	0.91	1.01	0.99	1.01	0.91	1.01	0.91	0.92	0.84	0.92	0.92
			Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.14	1.00	1.24	1.08	1.12	1.08	1.22	1.18	1.04	0.99	1.13	1.08	1.13	0.98	1.12	1.07	1.00	0.88	1.09	0.96	1.00	0.89	1.00	0.98
				DCP-CBR	1.11	0.98	1.12	1.06	1.10	1.09	1.22	1.18	1.03	0.99	1.04	1.07	1.13	0.99	1.13	1.08	1.00	0.90	1.09	0.97	1.00	0.91	1.04	1.01
				ORN31	1.16	1.02	1.16	1.02	1.05	1.02	1.13	1.11	1.05	1.00	1.05	1.00	1.05	0.91	1.03	0.99	1.02	0.90	1.02	0.90	0.93	0.83	0.92	0.91
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.18	0.98	1.28	1.07	1.15	1.07	1.25	1.16	1.08	0.98	1.17	1.07	1.17	0.98	1.16	1.06	0.99	0.84	1.08	0.92	0.99	0.86	0.99	0.94
				DCP-CBR	1.11	0.93	1.12	1.01	1.10	1.09	1.27	1.17	1.06	0.99	1.09	1.05	1.18	1.00	1.17	1.08	1.00	0.88	1.08	0.95	1.00	0.89	1.05	0.99
				ORN31	1.22	1.02	1.22	1.02	1.10	1.02	1.18	1.10	1.10	1.00	1.10	1.00	1.10	0.92	1.08	0.99	1.02	0.87	1.02	0.87	0.94	0.81	0.93	0.89
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.27	0.95	1.37	1.02	1.24	1.02	1.34	1.10	1.19	0.97	1.28	1.04	1.28	0.96	1.26	1.04	0.97	0.77	1.05	0.83	0.97	0.78	0.97	0.87
				DCP-CBR	1.11	0.83	1.12	0.90	1.10	1.08	1.40	1.15	1.17	0.99	1.22	1.03	1.31	1.02	1.29	1.07	1.00	0.84	1.08	0.90	1.00	0.86	1.08	0.94
				ORN31	1.36	1.01	1.36	1.01	1.23	1.01	1.32	1.09	1.23	1.00	1.23	1.00	1.23	0.93	1.20	0.99	1.04	0.82	1.04	0.82	0.96	0.77	0.95	0.86

(8) Project Costs Ratios (Cont'd)

Available materials/ Free haul	NG55	Cost of layer/s import	Zero Haulage	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.22	1.09	1.10	1.09	1.20	1.19	1.02	0.99	1.11	1.08	1.11	0.99	1.10	1.07	1.00	0.90	1.10	0.99	1.00	0.91	1.00	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.99	1.01	1.07	1.11	0.99	1.11	1.08	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11	1.03	1.00	1.03	1.00	1.03	0.91	1.01	0.99	1.01	0.91	1.01	0.91	0.92	0.84	0.92	0.92
			Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.14	1.02	1.24	1.11	1.12	1.11	1.22	1.21	1.04	0.99	1.13	1.08	1.13	0.98	1.12	1.07	1.00	0.90	1.09	0.98	1.00	0.91	1.00	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.22	1.21	1.01	0.97	1.01	1.05	1.11	0.99	1.13	1.08	1.00	0.91	1.09	0.99	1.00	0.93	1.04	1.03
				ORN31	1.16	1.04	1.16	1.04	1.05	1.04	1.13	1.13	1.05	1.00	1.05	1.00	1.05	0.91	1.03	0.99	1.02	0.91	1.02	0.91	0.93	0.84	0.92	0.93
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.18	1.05	1.28	1.14	1.15	1.14	1.25	1.24	1.08	0.98	1.17	1.07	1.17	0.98	1.16	1.06	0.99	0.89	1.08	0.98	0.99	0.90	0.99	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.27	1.26	1.01	0.92	1.01	1.00	1.11	1.00	1.17	1.08	1.00	0.93	1.08	1.01	1.00	0.94	1.05	1.04
				ORN31	1.22	1.09	1.22	1.09	1.10	1.09	1.18	1.18	1.10	1.00	1.10	1.00	1.10	0.92	1.08	0.99	1.02	0.92	1.02	0.92	0.94	0.85	0.93	0.94
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.27	1.14	1.37	1.23	1.24	1.23	1.34	1.33	1.19	0.97	1.28	1.04	1.28	0.96	1.26	1.04	0.97	0.89	1.05	0.96	0.97	0.89	0.97	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.40	1.39	1.01	0.82	1.01	0.89	1.11	1.02	1.29	1.07	1.00	0.97	1.08	1.04	1.00	0.98	1.08	1.07
				ORN31	1.36	1.22	1.36	1.22	1.23	1.22	1.32	1.31	1.23	1.00	1.23	1.00	1.23	0.93	1.20	0.99	1.04	0.95	1.04	0.95	0.96	0.88	0.95	0.98
	NG65	Cost of layer/s import	Zero Haulage	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.22	1.09	1.10	1.09	1.20	1.19	1.02	0.99	1.11	1.08	1.11	0.99	1.10	1.07	1.00	0.90	1.10	0.99	1.00	0.91	1.00	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.99	1.01	1.07	1.11	0.99	1.11	1.08	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11	1.03	1.00	1.03	1.00	1.03	0.91	1.01	0.99	1.01	0.91	1.01	0.91	0.92	0.84	0.92	0.92
			Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.14	1.02	1.24	1.11	1.12	1.11	1.22	1.21	1.13	1.08	1.13	1.08	1.13	0.98	1.12	1.07	1.02	0.90	1.11	0.98	1.02	0.91	1.02	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.97	1.01	1.05	1.11	0.97	1.13	1.08	1.00	0.89	1.09	0.97	1.00	0.93	1.06	1.03
				ORN31	1.16	1.04	1.16	1.04	1.05	1.04	1.13	1.13	1.05	1.00	1.05	1.00	1.05	0.91	1.03	0.99	1.04	0.91	1.04	0.91	0.95	0.84	0.94	0.93
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.18	1.05	1.28	1.14	1.15	1.14	1.25	1.24	1.08	0.98	1.17	1.07	1.17	0.98	1.16	1.06	1.06	0.89	1.16	0.98	1.05	0.90	1.05	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.92	1.01	1.00	1.11	0.93	1.17	1.08	1.00	0.85	1.09	0.93	1.00	0.94	1.12	1.04
				ORN31	1.22	1.09	1.22	1.09	1.10	1.09	1.18	1.18	1.10	1.00	1.10	1.00	1.10	0.92	1.08	0.99	1.09	0.92	1.09	0.92	1.00	0.85	0.99	0.94
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.27	1.14	1.37	1.23	1.24	1.23	1.34	1.33	1.19	0.97	1.28	1.04	1.28	0.96	1.26	1.04	1.17	0.89	1.26	0.96	1.15	0.89	1.13	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.82	1.01	0.89	1.11	0.84	1.29	1.07	1.00	0.77	1.09	0.84	1.00	0.98	1.26	1.07
				ORN31	1.36	1.22	1.36	1.22	1.23	1.22	1.32	1.31	1.23	1.00	1.23	1.00	1.23	0.93	1.20	0.99	1.24	0.95	1.24	0.95	1.14	0.88	1.11	0.98
	NG80	Cost of layer/s import	Zero Haulage	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.22	1.09	1.10	1.09	1.20	1.19	1.02	0.99	1.11	1.08	1.11	0.99	1.10	1.07	1.00	0.90	1.10	0.99	1.00	0.91	1.00	0.99
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.99	1.01	1.07	1.11	0.99	1.11	1.08	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11	1.03	1.00	1.03	1.00	1.03	0.91	1.01	0.99	1.01	0.91	1.01	0.91	0.92	0.84	0.92	0.92
			Low	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.23	1.10	1.11	1.10	1.21	1.20	1.02	0.99	1.12	1.09	1.12	0.98	1.11	1.06	1.00	0.90	1.11	0.99	1.01	0.91	1.01	1.00
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.99	1.01	1.07	1.11	0.97	1.11	1.06	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11	1.03	1.00	1.03	1.00	1.03	0.89	1.01	0.97	1.01	0.91	1.01	0.91	0.92	0.84	0.94	0.94
			Medium	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.23	1.10	1.11	1.10	1.21	1.20	1.02	0.99	1.12	1.09	1.12	0.94	1.11	1.02	1.00	0.90	1.11	0.99	1.01	0.91	1.01	1.00
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.99	1.01	1.07	1.11	0.93	1.11	1.02	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11	1.03	1.00	1.03	1.00	1.03	0.86	1.01	0.93	1.01	0.91	1.01	0.91	0.92	0.84	0.92	0.92
			High	DCP-DN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				TRH4	1.12	1.00	1.23	1.10	1.11	1.10	1.21	1.20	1.12	1.09	1.12	1.09	1.12	0.84	1.11	0.92	1.00	0.90	1.11	0.99	1.01	0.91	1.01	1.00
				DCP-CBR	1.11	1.00	1.12	1.08	1.10	1.10	1.20	1.19	1.01	0.99	1.01	1.07	1.11	0.84	1.11	0.92	1.00	0.90	1.09	0.99	1.00	0.92	1.04	1.02
				ORN31	1.14	1.02	1.14	1.02	1.03	1.02	1.11	1.11	1.03	1.00	1.03	1.00	1.03	0.77	1.01	0.84	1.01	0.91	1.01	0.91	0.92	0.84	0.92	0.92

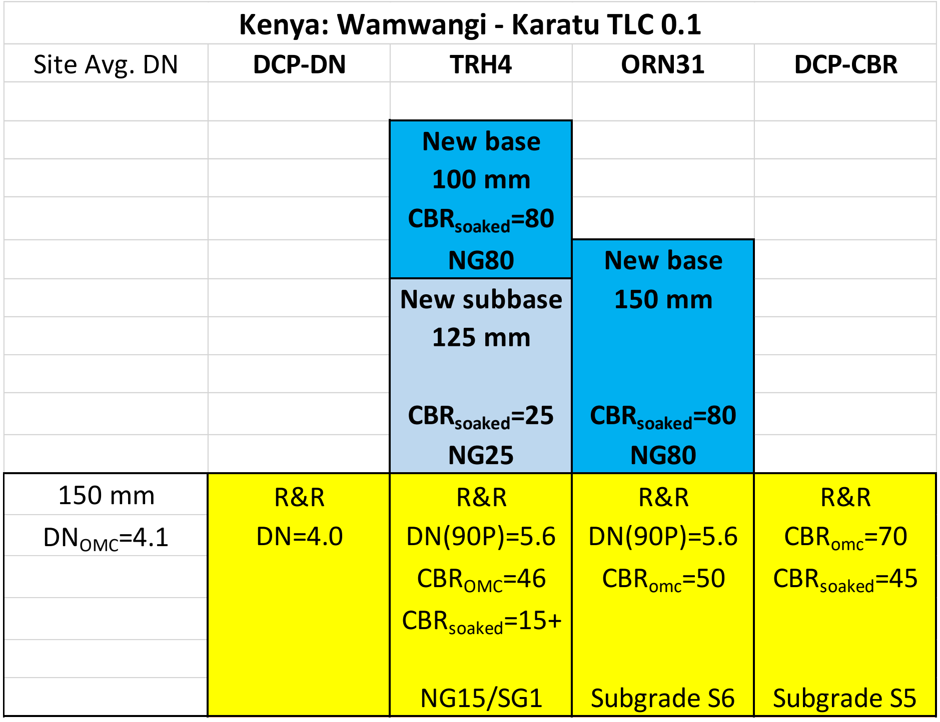
9. Project Cost Savings/km

Project cost savings per km					USD per km of 6.5m wide																							
Traffic					Low (< 0.1 MESA)								Medium (0.1 - 0.3 MESA)								High (0.3 - 1.0 MESA)							
ORN31 subgrade class					Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)	Good (S6)	Good (S6)	Good (S6)	Good (S6)	Fair (S6)	Fair (S6)	Poor (S5)	Poor S4)
Subgrade					VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)		VG (NG30)	VG (NG30)	Good (NG15)		Fair (NG7)		Poor (NG3)	
Climate					Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet	Dry - Moderate	Wet
Available materials / Free haul	NG15	Cost of layer/s import	Zero Haulage	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	13,310	360	24,372	11,422	12,501	11,422	24,372	23,298	2,338	-899	13,400	10,162	13,400	-1,709	13,400	10,162	26	-13,830	11,897	-1,979	26	-13,830	26	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-1,542	1,696	8,773	12,784	-1,169	14,326	11,088	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	15,109	2,138	15,109	2,138	3,238	2,138	13,490	13,220	3,238	0	3,238	0	3,238	-11,871	1,619	-809	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-12,012	-12,100
			Low	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	15,109	-540	28,419	12,771	16,548	12,771	28,419	24,642	1,889	-1,349	15,199	11,961	15,199	90	15,199	11,961	-424	-16,997	14,145	-2,428	2,274	-14,299	2,274	-1,079
				DCP-CBR	14,355	0	15,648	11,953	14,865	13,863	28,509	24,732	383	-1,542	1,696	10,392	12,784	1,439	16,484	13,246	0	-14,833	13,246	-1,587	2,698	-11,201	9,654	4,951
				ORN31	17,807	2,138	17,807	2,138	5,936	2,138	17,987	15,469	3,238	0	3,238	0	3,238	-11,871	3,417	1,439	1,928	-14,645	1,928	-14,645	-9,943	-26,517	-9,763	-11,201
			Medium	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	19,066	-2,518	37,322	15,738	25,451	15,738	37,322	27,610	899	-2,338	19,156	15,918	19,156	4,047	19,156	15,918	-1,413	-23,922	19,092	-3,417	7,220	-15,289	7,220	-1,079
				DCP-CBR	19,103	0	21,584	15,514	20,801	18,612	39,194	29,481	-804	-1,542	1,696	13,954	12,784	7,177	21,233	17,995	0	-18,790	17,995	-795	8,634	-9,222	18,557	7,919
				ORN31	23,742	2,138	23,742	2,138	11,871	2,138	27,879	20,415	3,238	0	3,238	0	3,238	-11,871	7,375	6,385	2,917	-19,592	2,917	-19,592	-8,954	-31,463	-4,817	-9,222
			High	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	29,678	-7,824	61,200	23,698	49,329	23,698	61,200	35,569	-1,754	-4,991	29,768	26,530	29,768	14,639	29,768	26,530	-4,066	-42,494	32,357	-6,071	20,486	-17,942	20,486	-1,079
				DCP-CBR	31,838	0	37,502	25,065	36,719	31,346	67,846	42,215	-3,987	-1,542	1,696	23,504	12,784	22,565	33,967	30,730	0	-29,402	30,730	1,327	24,552	-3,916	42,434	15,878
				ORN31	39,661	2,138	39,661	2,138	27,789	2,138	54,410	33,680	3,238	0	3,238	0	3,238	-11,871	17,987	19,650	5,570	-32,857	5,570	-32,857	-6,301	-44,728	8,448	-3,916
	NG25/30	Cost of layer/s import	Zero Haulage	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	13,310	360	24,372	11,422	12,501	11,422	24,372	23,298	2,338	-899	13,400	10,162	13,400	-1,709	13,400	10,162	26	-13,830	11,897	-1,979	26	-13,830	26	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-1,542	1,696	8,773	12,784	-1,169	14,326	11,088	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	15,109	2,138	15,109	2,138	3,238	2,138	13,490	13,220	3,238	0	3,238	0	3,238	-11,871	1,619	-809	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-12,012	-12,100
			Low	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	15,109	-540	26,171	10,522	14,299	10,522	26,171	22,398	4,587	-1,349	15,648	9,713	15,648	-2,158	15,648	9,713	-424	-16,997	11,447	-5,126	-424	-16,997	-424	-3,777
				DCP-CBR	14,355	0	15,648	9,794	14,865	11,705	26,351	22,574	3,081	-1,542	4,394	8,234	15,482	-719	17,024	11,088	0	-14,833	11,088	-3,745	0	-13,899	6,506	1,804
				ORN31	17,807	2,138	17,807	2,138	5,936	2,138	16,188	13,220	5,936	0	5,936	0	5,936	-11,871	4,317	-809	1,928	-14,645	1,928	-14,645	-9,943	-26,517	-11,562	-13,899
			Medium	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	19,066	-2,518	30,128	8,544	18,257	8,544	30,128	20,415	9,533	-2,338	20,595	8,724	20,595	-3,148	20,595	8,724	-1,413	-23,922	10,458	-12,051	-1,413	-23,922	-1,413	-9,713
				DCP-CBR	19,103	0	21,584	8,607	20,801	11,705	32,287	22,574	7,830	-1,542	10,330	7,047	21,418	270	22,959	11,088	0	-18,790	11,088	-7,702	0	-17,856	8,485	-2,153
				ORN31	23,742	2,138	23,742	2,138	11,871	2,138	22,124	13,220	11,871	0	11,871	0	11,871	-11,871	10,252	-809	2,917	-19,592	2,917	-19,592	-8,954	-31,463	-10,573	-17,856
			High	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	29,678	-7,824	40,740	3,238	28,869	3,238	40,740	15,109	22,798	-4,991	33,860	6,071	33,860	-5,801	33,860	6,071	-4,066	-42,494	6,996	-31,432	-4,876	-43,308	-4,876	-26,440
				DCP-CBR	31,838	0	37,502	5,423	36,719	11,705	48,205	22,574	20,564	-1,542	26,248	3,863	37,336	2,923	38,878	11,088	0	-29,402	11,088	-18,314	0	-28,468	13,791	-12,766
				ORN31	39,661	2,138	39,661	2,138	27,789	2,138	38,042	13,220	27,789	0	27,789	0	27,789	-11,871	26,171	-809	5,570	-32,857	5,570	-32,857	-6,301	-44,728	-7,920	-28,468
	NG45	Cost of layer/s import	Zero Haulage	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	13,310	360	24,372	11,422	12,501	11,422	24,372	23,298	2,338	-899	13,400	10,162	13,400	-1,709	13,400	10,162	26	-13,830	11,897	-1,979	26	-13,830	26	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-1,542	1,696	8,773	12,784	-1,169	14,326	11,088	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	15,109	2,138	15,109	2,138	3,238	2,138	13,490	13,220	3,238	0	3,238	0	3,238	-11,871	1,619	-809	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-12,012	-12,100
			Low	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	15,109	-540	26,171	10,522	14,299	10,522	26,171	22,398	4,587	-1,349	15,648	9,713	15,648	-2,158	15,648	9,713	-424	-16,997	11,447	-5,126	-424	-16,997	-424	-3,777
				DCP-CBR	12,196	-2,688	12,950	7,636	12,167	11,705	26,351	22,574	3,081	-1,542	4,394	8,234	15,482	-719	17,024	11,088	0	-14,833	11,088	-3,745	0	-13,899	6,506	1,804
				ORN31	17,807	2,138	17,807	2,138	5,936	2,138	16,188	13,220	5,936	0	5,936	0	5,936	-11,871	4,317	-809	1,928	-14,645	1,928	-14,645	-9,943	-26,517	-11,562	-13,899
			Medium	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	19,066	-2,518	30,128	8,544	18,257	8,544	30,128	20,415	9,533	-2,338	20,595	8,724	20,595	-3,148	20,595	8,724	-1,413	-23,922	10,458	-12,051	-1,413	-23,922	-1,413	-9,713
				DCP-CBR	12,196	-8,634	12,950	1,700	12,167	11,705	32,287	22,574	7,830	-1,542	10,330	7,047	21,418	270	22,959	11,088	0	-18,790	11,088	-7,702	0	-17,856	8,485	-2,153
				ORN31	23,742	2,138	23,742	2,138	11,871	2,138	22,124	13,220	11,871	0	11,871	0	11,871	-11,871	10,252	-809	2,917	-19,592	2,917	-19,592	-8,954	-31,463	-10,573	-17,856
			High	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	29,678	-7,824	40,740	3,238	28,869	3,238	40,740	15,109	22,798	-4,991	33,860	6,071	33,860	-5,801	33,860	6,071	-4,066	-42,494	6,996	-31,432	-4,876	-43,308	-4,876	-26,440
				DCP-CBR	12,196	-24,552	12,950	-14,218	12,167	11,705	48,205	22,574	20,564	-1,542	26,248	3,863	37,336	2,923	38,878	11,088	0	-29,402	11,088	-18,314	0	-28,468	13,791	-12,766
				ORN31	39,661	2,138	39,661	2,138	27,789	2,138	38,042	13,220	27,789	0	27,789	0	27,789	-11,871	26,171	-809	5,570	-32,857	5,570	-32,857	-6,301	-44,728	-7,920	-28,468

10. Project Cost Savings/km (Cont'd)

Available materials/ Free haul	NG55	Cost of layer/s import	Zero Haulage	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	13,310	360	24,372	11,422	12,501	11,422	24,372	23,298	2,338	899	13,400	10,162	13,400	-1,709	13,400	10,162	26	-13,830	11,897	-1,979	26	-13,830	26	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-1,542	1,696	8,773	12,784	-1,169	14,326	11,088	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	15,109	2,158	15,109	2,158	3,238	2,158	13,490	13,220	3,238	0	3,238	0	3,238	-11,871	1,619	-809	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-12,012	-12,100
			Low	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	15,109	2,158	26,171	13,220	14,299	13,220	26,171	25,091	4,587	-1,349	15,648	9,713	15,648	-2,158	15,648	9,713	-424	-14,299	11,447	-2,428	-424	-14,299	-424	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	26,351	25,272	923	-4,240	1,696	6,075	12,784	-719	17,024	11,088	0	-12,135	11,088	-1,047	0	-11,201	6,506	4,502
				ORN31	17,807	4,836	17,807	4,836	5,936	4,836	16,188	15,918	5,936	0	5,936	0	5,936	-11,871	4,317	-809	1,928	-11,947	1,928	-11,947	-9,943	-23,819	-11,962	-11,201
			Medium	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	19,066	6,115	30,128	17,177	18,257	17,177	30,128	29,048	9,533	-2,338	20,595	8,724	20,595	-3,148	20,595	8,724	-1,413	-15,289	10,458	-3,417	-1,413	-15,289	-1,413	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	32,287	31,207	923	-10,175	1,696	140	12,784	270	22,959	11,088	0	-10,157	11,088	932	0	-9,222	8,485	6,480
				ORN31	23,742	10,792	23,742	10,792	11,871	10,792	22,124	21,854	11,871	0	11,871	0	11,871	-11,871	10,252	-809	2,917	-10,958	2,917	-10,958	-8,954	-22,829	-10,573	-9,222
			High	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	29,678	16,728	40,740	27,789	28,869	27,789	40,740	39,661	22,798	-4,991	33,860	6,071	33,860	-5,801	33,860	6,071	-4,066	-17,942	6,996	-6,880	-4,876	-18,751	-4,876	-1,889
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	48,205	47,126	923	-26,094	1,696	-15,779	12,784	2,923	38,878	11,088	0	-4,850	11,088	6,238	0	-3,916	13,791	11,786
				ORN31	39,661	26,710	39,661	26,710	27,789	26,710	38,042	37,772	27,789	0	27,789	0	27,789	-11,871	26,171	-809	5,570	-8,305	5,570	-8,305	-6,301	-20,176	-7,920	-3,916
	NG65	Cost of layer/s import	Zero Haulage	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	13,310	360	24,372	11,422	12,501	11,422	24,372	23,298	2,338	899	13,400	10,162	13,400	-1,709	13,400	10,162	26	-13,830	11,897	-1,979	26	-13,830	26	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-1,542	1,696	8,773	12,784	-1,169	14,326	11,088	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	15,109	2,158	15,109	2,158	3,238	2,158	13,490	13,220	3,238	0	3,238	0	3,238	-11,871	1,619	-809	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-12,012	-12,100
			Low	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	15,109	2,158	26,171	13,220	14,299	13,220	26,171	25,091	15,648	9,713	15,648	9,713	15,648	-2,158	15,648	9,713	2,274	-14,299	14,145	-2,428	2,274	-14,299	2,274	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-4,240	1,696	6,075	12,784	-3,867	17,024	11,088	0	-15,732	11,088	-4,644	0	-11,201	9,204	4,502
				ORN31	17,807	4,836	17,807	4,836	5,936	4,836	16,188	15,918	5,936	0	5,936	0	5,936	-11,871	4,317	-809	4,626	-11,947	4,626	-11,947	-7,246	-23,819	-8,864	-11,201
			Medium	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	19,066	6,115	30,128	17,177	18,257	17,177	30,128	29,048	9,533	-2,338	20,595	8,724	20,595	-3,148	20,595	8,724	7,220	-15,289	19,092	-3,417	7,220	-15,289	7,220	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-10,175	1,696	140	12,784	-9,802	22,959	11,088	0	-21,668	11,088	-10,580	0	-9,222	17,118	6,480
				ORN31	23,742	10,792	23,742	10,792	11,871	10,792	22,124	21,854	11,871	0	11,871	0	11,871	-11,871	10,252	-809	11,551	-10,958	11,551	-10,958	-320	-22,829	-1,939	-9,222
			High	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	29,678	16,728	40,740	27,789	28,869	27,789	40,740	39,661	22,798	-4,991	33,860	6,071	33,860	-5,801	33,860	6,071	20,486	-17,942	31,547	-6,880	19,676	-18,751	19,676	-1,889
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-26,094	1,696	-15,779	12,784	-25,720	38,878	11,088	0	-37,586	11,088	-26,498	0	-3,916	38,342	11,786
				ORN31	39,661	26,710	39,661	26,710	27,789	26,710	38,042	37,772	27,789	0	27,789	0	27,789	-11,871	26,171	-809	30,122	-8,305	30,122	-8,305	18,251	-20,176	16,632	-3,916
	NG80	Cost of layer/s import	Zero Haulage	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	13,310	360	24,372	11,422	12,501	11,422	24,372	23,298	2,338	899	13,400	10,162	13,400	-1,709	13,400	10,162	26	-13,830	11,897	-1,979	26	-13,830	26	-1,079
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-1,542	1,696	8,773	12,784	-1,169	14,326	11,088	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	15,109	2,158	15,109	2,158	3,238	2,158	13,490	13,220	3,238	0	3,238	0	3,238	-11,871	1,619	-809	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-12,012	-12,100
			Low	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	13,310	360	25,451	12,501	13,580	12,501	25,451	24,372	2,338	899	14,479	11,242	14,479	-3,328	14,479	8,544	26	-13,830	12,976	899	1,105	-12,771	1,105	0
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-1,542	1,696	8,773	12,784	-3,867	14,326	8,390	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	15,109	2,158	15,109	2,158	3,238	2,158	13,490	13,220	3,238	0	3,238	0	3,238	-14,569	1,619	-3,507	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-8,864	-8,503
			Medium	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	13,310	360	25,451	12,501	13,580	12,501	25,451	24,372	2,338	899	14,479	11,242	14,479	-9,263	14,479	2,608	26	-13,830	12,976	899	1,105	-12,771	1,105	0
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-1,542	1,696	8,773	12,784	-9,802	14,326	2,454	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	15,109	2,158	15,109	2,158	3,238	2,158	13,490	13,220	3,238	0	3,238	0	3,238	-20,505	1,619	-9,443	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-12,012	-12,100
			High	DCP-DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				TRH4	13,310	360	25,451	12,501	13,580	12,501	25,451	24,372	14,479	11,242	14,479	11,242	14,479	-25,181	14,479	-13,310	26	-13,830	12,976	899	1,105	-12,771	1,105	0
				DCP-CBR	12,196	0	12,950	10,334	12,167	11,705	23,653	22,574	923	-1,542	1,696	8,773	12,784	-25,720	14,326	-13,464	0	-13,034	11,088	-1,946	0	-12,100	5,607	3,602
				ORN31	15,109	2,158	15,109	2,158	3,238	2,158	13,490	13,220	3,238	0	3,238	0	3,238	-36,423	1,619	-25,361	1,478	-12,397	1,478	-12,397	-10,393	-24,268	-12,012	-12,100

Annex I - Pavement structures and costs by TLCs for different design methods



Kenya: Wamwangi - Karatu TLC 0.1				
Site Avg. DN	**DCP-DN**	**TRH4**	**ORN31**	**DCP-CBR**
		New base 100 mm CBR_{soaked}=80 NG80		
		New subbase 125 mm CBR_{soaked}=25 NG25	**New base 150 mm CBR_{soaked}=80 NG80**	
150 mm DN_{OMC}=4.1	R&R DN=4.0	R&R DN(90P)=5.6 CBR_{OMC}=46 CBR_{soaked}=15+ NG15/SG1	R&R DN(90P)=5.6 CBR_{omc}=50 Subgrade S6	R&R CBR_{omc}=70 CBR_{soaked}=45 Subgrade S5

Possible Unlikely

Cost for 6.5 m wide pavement incl. 100 mm rip, shape and recompact of in situ wearing course

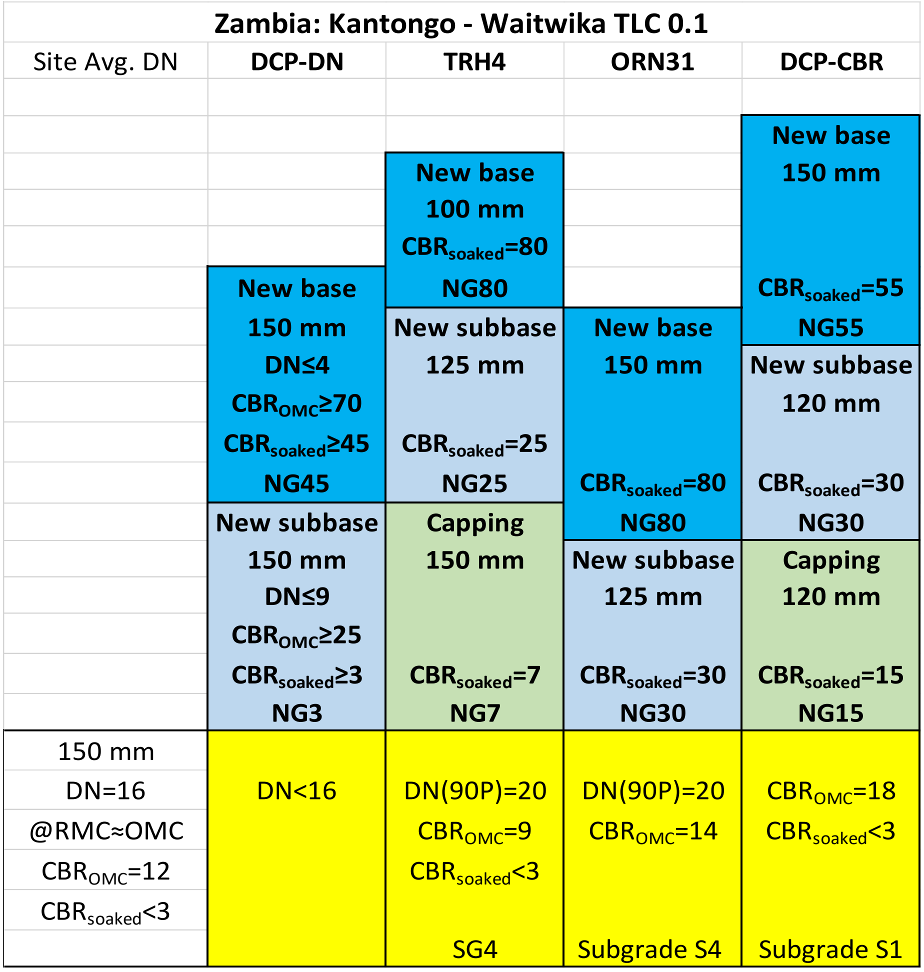
USD/km

DCP-DN		Zero haulage		2438
		Base not required		
Avg. haul km		**5**	**20**	**65**
Subbase not required	**0**	2 438	2 438	2 438
	0			
	0			

ORN31		Zero haulage		12458
		Base 150 mm NG80		
Avg. haul km		**5**	**20**	**65**
Subbase not required	**0**	13 813	16 792	24 781
	0			
	0			

TRH4		Zero haulage		20786
		Base 100 mm NG80		
Avg. haul km		**5**	**20**	**65**
125 mm NG25 Subbase	**5**	23 833	26 813	34 802
	20	26 813	30 536	38 526
	65	37 544	40 523	48 513

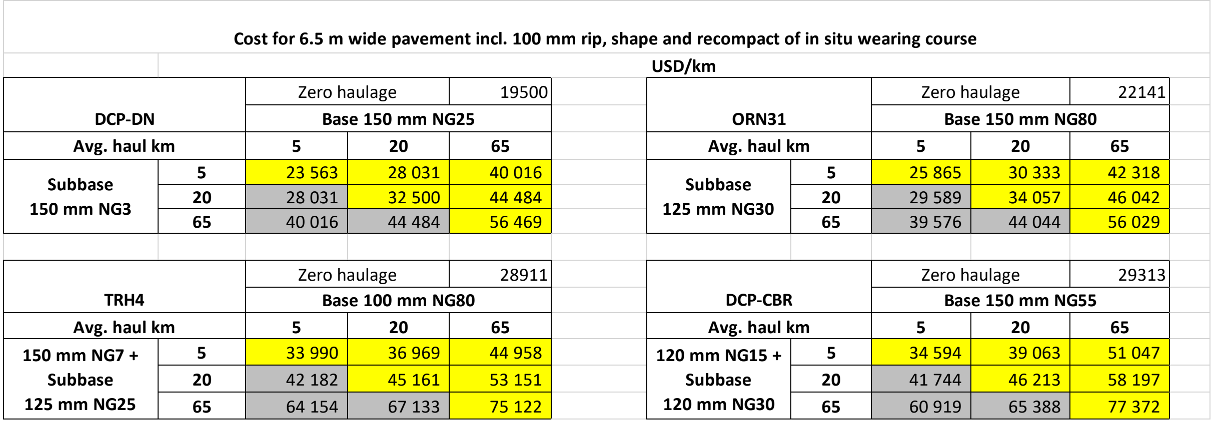
DCP-CBR		Zero haulage		2438
		Base not required		
Avg. haul km		**5**	**20**	**65**
Subbase not required	**0**	2 438	2 438	2 438
	0	-	-	-
	0	-	-	-



Zambia: Kantongo - Waitwika TLC 0.1

Site Avg. DN	**DCP-DN**	**TRH4**	**ORN31**	**DCP-CBR**
	New base **150 mm** **DN≤4** **CBR_{OMC}≥70** **CBR_{soaked}≥45** **NG45**	**New base** **100 mm** **CBR_{soaked}=80** **NG80**	**New base** **150 mm** **CBR_{soaked}=80** **NG80**	**New base** **150 mm** **CBR_{soaked}=55** **NG55**
	New subbase **150 mm** **DN≤9** **CBR_{OMC}≥25** **CBR_{soaked}≥3** **NG3**	**New subbase** **125 mm** **CBR_{soaked}=25** **NG25**	**New subbase** **125 mm** **CBR_{soaked}=30** **NG30**	**New subbase** **120 mm** **CBR_{soaked}=30** **NG30**
		Capping **150 mm** **CBR_{soaked}=7** **NG7**		**Capping** **120 mm** **CBR_{soaked}=15** **NG15**
150 mm DN=16 @RMC≈OMC CBR_{OMC}=12 CBR_{soaked}<3	DN<16	DN(90P)=20 CBR_{OMC}=9 CBR_{soaked}<3 SG4	DN(90P)=20 CBR_{OMC}=14 Subgrade S4	CBR_{OMC}=18 CBR_{soaked}<3 Subgrade S1

Possible Unlikely



Cost for 6.5 m wide pavement incl. 100 mm rip, shape and recompact of in situ wearing course

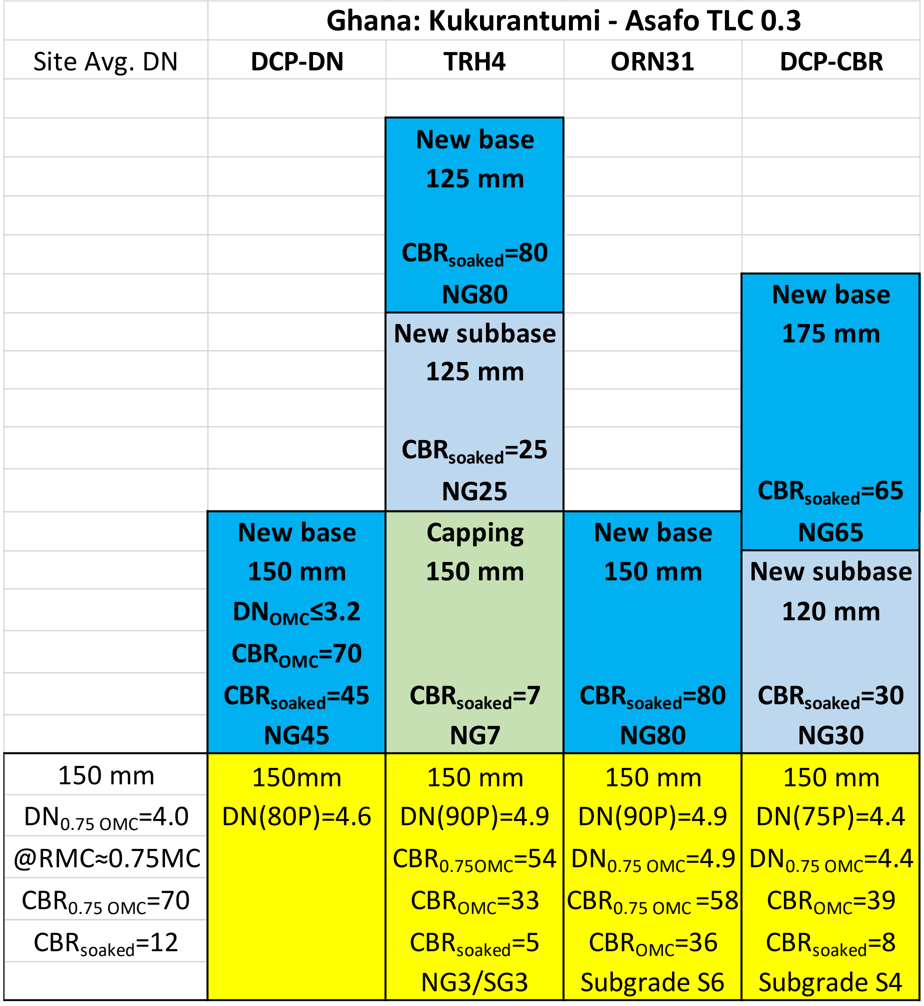
USD/km

DCP-DN		Zero haulage		19500
		Base 150 mm NG25		
Avg. haul km		**5**	**20**	**65**
Subbase 150 mm NG3	**5**	23 563	28 031	40 016
	20	28 031	32 500	44 484
	65	40 016	44 484	56 469

ORN31		Zero haulage		22141
		Base 150 mm NG80		
Avg. haul km		**5**	**20**	**65**
Subbase 125 mm NG30	**5**	25 865	30 333	42 318
	20	29 589	34 057	46 042
	65	39 576	44 044	56 029

TRH4		Zero haulage		28911
		Base 100 mm NG80		
Avg. haul km		**5**	**20**	**65**
150 mm NG7 + Subbase 125 mm NG25	**5**	33 990	36 969	44 958
	20	42 182	45 161	53 151
	65	64 154	67 133	75 122

DCP-CBR		Zero haulage		29313
		Base 150 mm NG55		
Avg. haul km		**5**	**20**	**65**
120 mm NG15 + Subbase 120 mm NG30	**5**	34 594	39 063	51 047
	20	41 744	46 213	58 197
	65	60 919	65 388	77 372



	Ghana: Kukurantumi - Asafo TLC 0.3			
Site Avg. DN	DCP-DN	TRH4	ORN31	DCP-CBR
		New base 125 mm CBR_{soaked}=80 NG80		
		New subbase 125 mm CBR_{soaked}=25 NG25		New base 175 mm CBR_{soaked}=65 NG65
	New base 150 mm DN_{OMC}≤3.2 CBR_{OMC}=70 CBR_{soaked}=45 NG45	Capping 150 mm CBR_{soaked}=7 NG7	New base 150 mm CBR_{soaked}=80 NG80	New subbase 120 mm CBR_{soaked}=30 NG30
150 mm $DN_{0.75\ OMC}$=4.0 @RMC≈0.75MC $CBR_{0.75\ OMC}$=70 CBR_{soaked}=12	150mm DN(80P)=4.6	150 mm DN(90P)=4.9 $CBR_{0.75OMC}$=54 CBR_{OMC}=33 CBR_{soaked}=5 NG3/SG3	150 mm DN(90P)=4.9 $DN_{0.75\ OMC}$=4.9 $CBR_{0.75\ OMC}$=58 CBR_{OMC}=36 Subgrade S6	150 mm DN(75P)=4.4 $DN_{0.75\ OMC}$=4.4 CBR_{OMC}=39 CBR_{soaked}=8 Subgrade S4

Possible Unlikely

Cost for 6.5 m wide pavement incl. 100 mm rip, shape and recompact of in situ wearing course

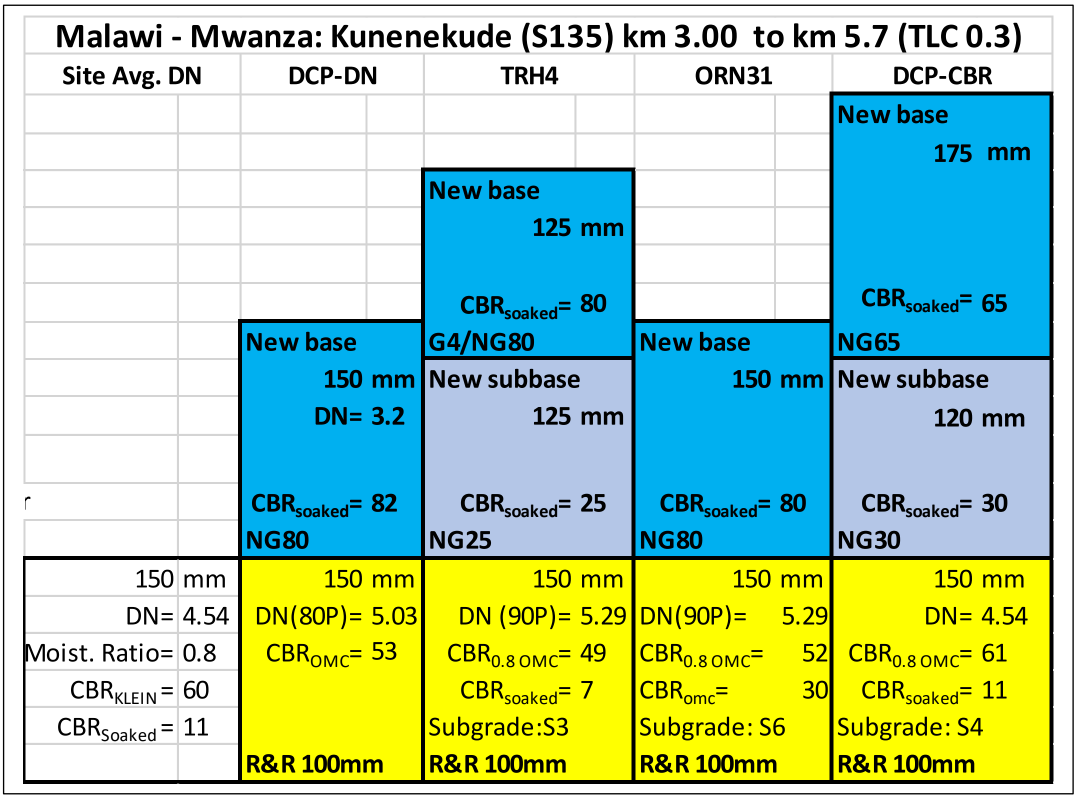
USD/km

DCP-DN		Zero haulage		12188
		Base 150 mm NG25		
Avg. haul km		**5**	**20**	**65**
Subbase not required	**0**	14 219	20 313	38 594
	0			
	0			

ORN31		Zero haulage		13813
		Base 150 mm NG80		
Avg. haul km		**5**	**20**	**65**
Subbase not required	**0**	15 844	21 938	40 219
	0			
	0			

TRH4		Zero haulage		29589
		Base 125 mm NG80		
Avg. haul km		**5**	**20**	**65**
150 mm NG7 + Subbase 125 mm NG25	**5**	35 005	38 729	48 716
	20	43 198	46 922	56 909
	65	65 169	68 893	78 880

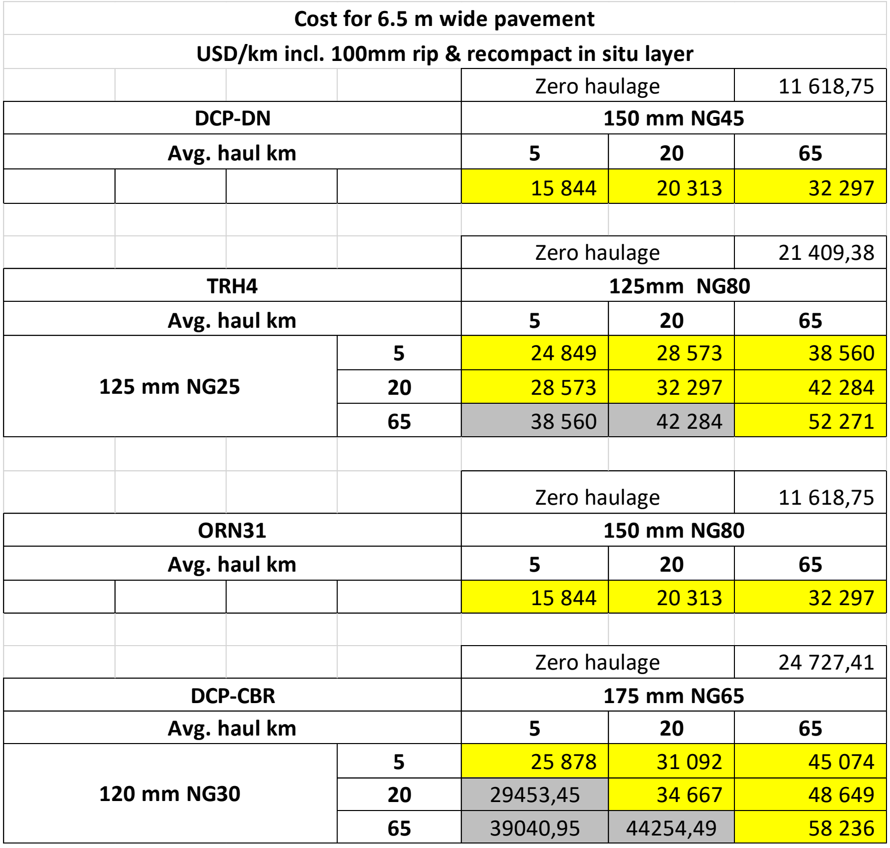
DCP-CBR		Zero haulage		18685
		Base 175 mm NG65		
Avg. haul km		**5**	**20**	**65**
Subbase 120 mm NG30	**5**	25 879	31 092	45 074
	20	29 454	34 667	48 649
	65	39 041	44 255	58 236



Malawi - Mwanza: Kunenekude (S135) km 3.00 to km 5.7 (TLC 0.3)

Site Avg. DN	DCP-DN	TRH4	ORN31	DCP-CBR
		New base 125 mm CBR_{soaked}= 80 G4/NG80		New base 175 mm CBR_{soaked}= 65 NG65
	New base 150 mm DN= 3.2 CBR_{soaked}= 82 NG80	New subbase 125 mm CBR_{soaked}= 25 NG25	New base 150 mm CBR_{soaked}= 80 NG80	New subbase 120 mm CBR_{soaked}= 30 NG30
150 mm DN= 4.54 Moist. Ratio= 0.8 CBR_{KLEIN} = 60 CBR_{Soaked} = 11	150 mm DN(80P)= 5.03 CBR_{OMC}= 53 R&R 100mm	150 mm DN (90P)= 5.29 $CBR_{0.8\,OMC}$= 49 CBR_{soaked}= 7 Subgrade:S3 R&R 100mm	150 mm DN(90P)= 5.29 $CBR_{0.8\,OMC}$= 52 CBR_{omc}= 30 Subgrade: S6 R&R 100mm	150 mm DN= 4.54 $CBR_{0.8\,OMC}$= 61 CBR_{soaked}= 11 Subgrade: S4 R&R 100mm

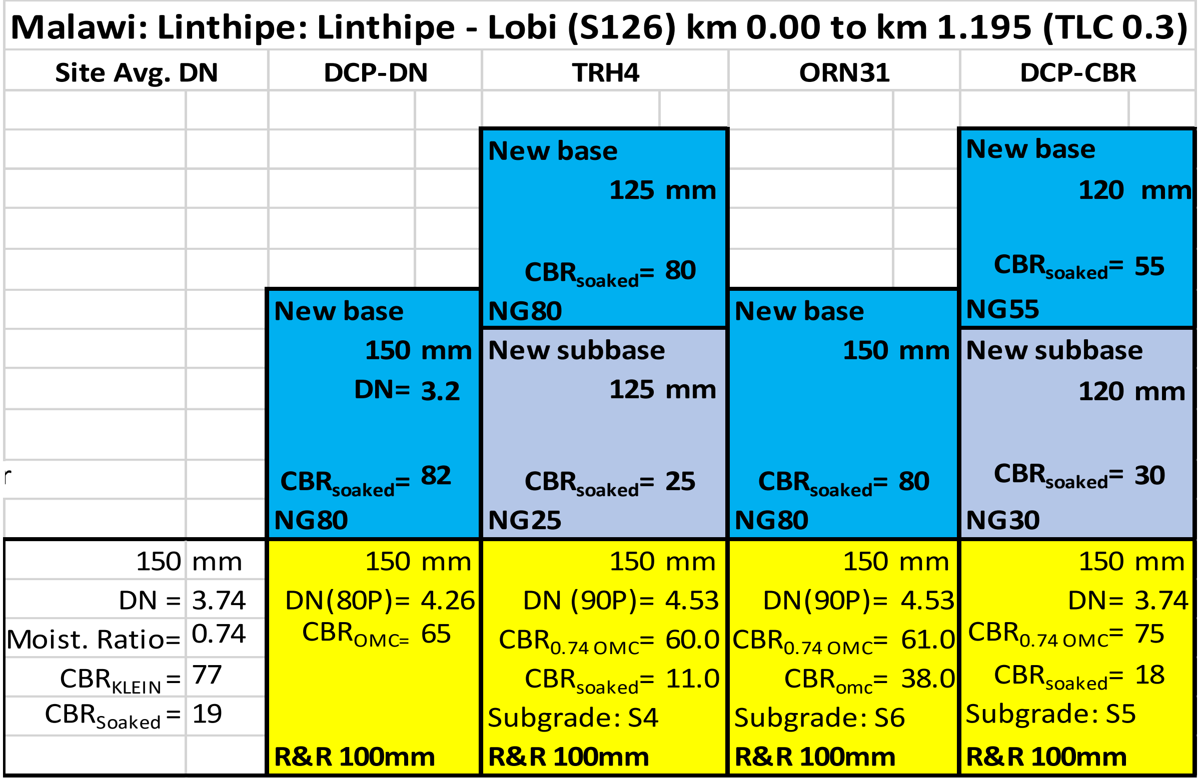
Possible Unlikely



Cost for 6.5 m wide pavement

USD/km incl. 100mm rip & recompact in situ layer

		Zero haulage		11 618,75
DCP-DN		**150 mm NG45**		
Avg. haul km		**5**	**20**	**65**
		15 844	20 313	32 297
		Zero haulage		21 409,38
TRH4		**125mm NG80**		
Avg. haul km		**5**	**20**	**65**
125 mm NG25	**5**	24 849	28 573	38 560
	20	28 573	32 297	42 284
	65	38 560	42 284	52 271
		Zero haulage		11 618,75
ORN31		**150 mm NG80**		
Avg. haul km		**5**	**20**	**65**
		15 844	20 313	32 297
		Zero haulage		24 727,41
DCP-CBR		**175 mm NG65**		
Avg. haul km		**5**	**20**	**65**
120 mm NG30	**5**	25 878	31 092	45 074
	20	29453,45	34 667	48 649
	65	39040,95	44254,49	58 236



Malawi: Linthipe: Linthipe - Lobi (S126) km 0.00 to km 1.195 (TLC 0.3)

Site Avg. DN	DCP-DN	TRH4	ORN31	DCP-CBR
		New base 125 mm CBR_{soaked}= 80 NG80		New base 120 mm CBR_{soaked}= 55 NG55
	New base 150 mm DN= 3.2 CBR_{soaked}= 82 NG80	New subbase 125 mm CBR_{soaked}= 25 NG25	New base 150 mm CBR_{soaked}= 80 NG80	New subbase 120 mm CBR_{soaked}= 30 NG30
150 mm DN = 3.74 Moist. Ratio= 0.74 CBR_{KLEIN} = 77 CBR_{Soaked} = 19	150 mm DN(80P)= 4.26 $CBR_{OMC=}$ 65 R&R 100mm	150 mm DN (90P)= 4.53 $CBR_{0.74\ OMC}$= 60.0 CBR_{soaked}= 11.0 Subgrade: S4 R&R 100mm	150 mm DN(90P)= 4.53 $CBR_{0.74\ OMC}$= 61.0 CBR_{omc}= 38.0 Subgrade: S6 R&R 100mm	150 mm DN= 3.74 $CBR_{0.74\ OMC}$= 75 CBR_{soaked}= 18 Subgrade: S5 R&R 100mm

Possible Unlikely

Cost for 6.5 m wide pavement

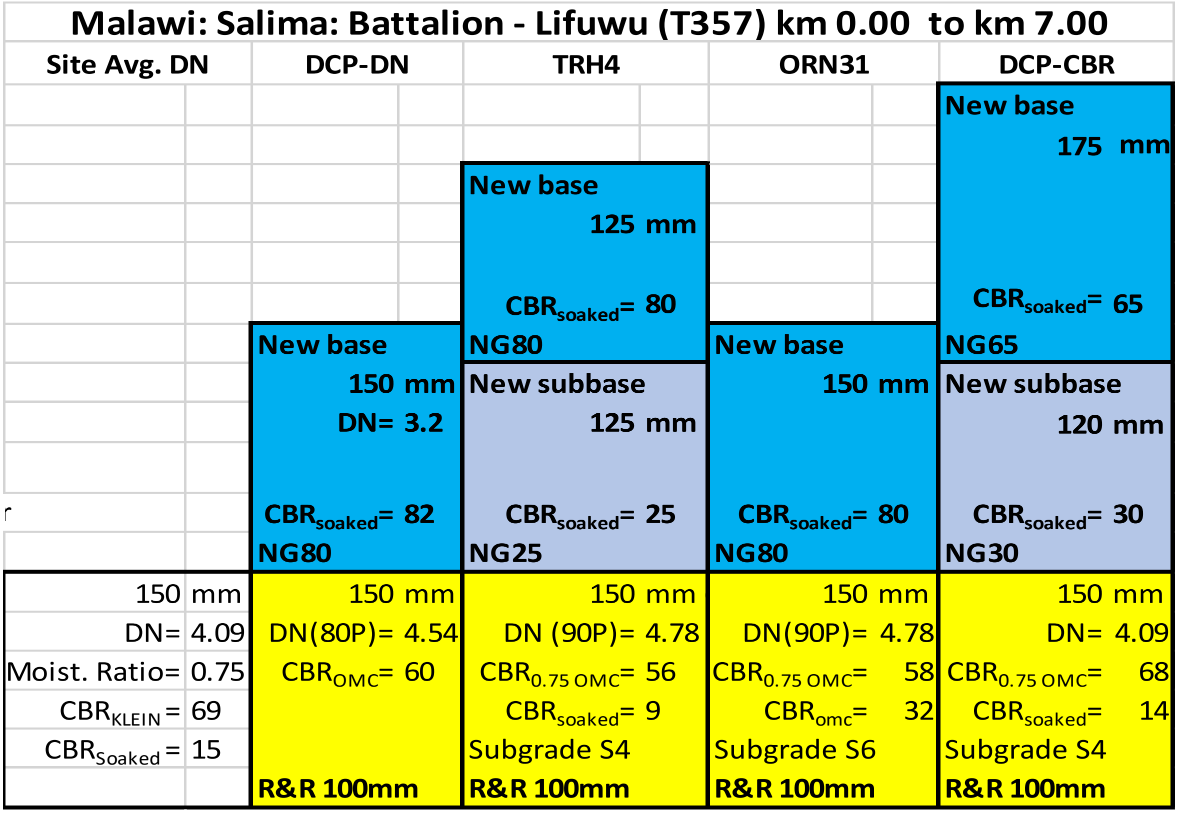
USD/km incl. 100mm rip & recompact in situ layer

		Zero haulage		11 618,75
DCP-DN		**150 mm NG80**		
Avg. haul km		**5**	**20**	**65**
		15 844	20 313	32 297

		Zero haulage		19 269,79
TRH4		**125 mm NG80**		
Avg. haul km		**5**	**20**	**65**
125 mm NG25	**5**	43 875	51 323	71 297
	20	51 323	58 771	78 745
	65	71 297	78 745	98 719

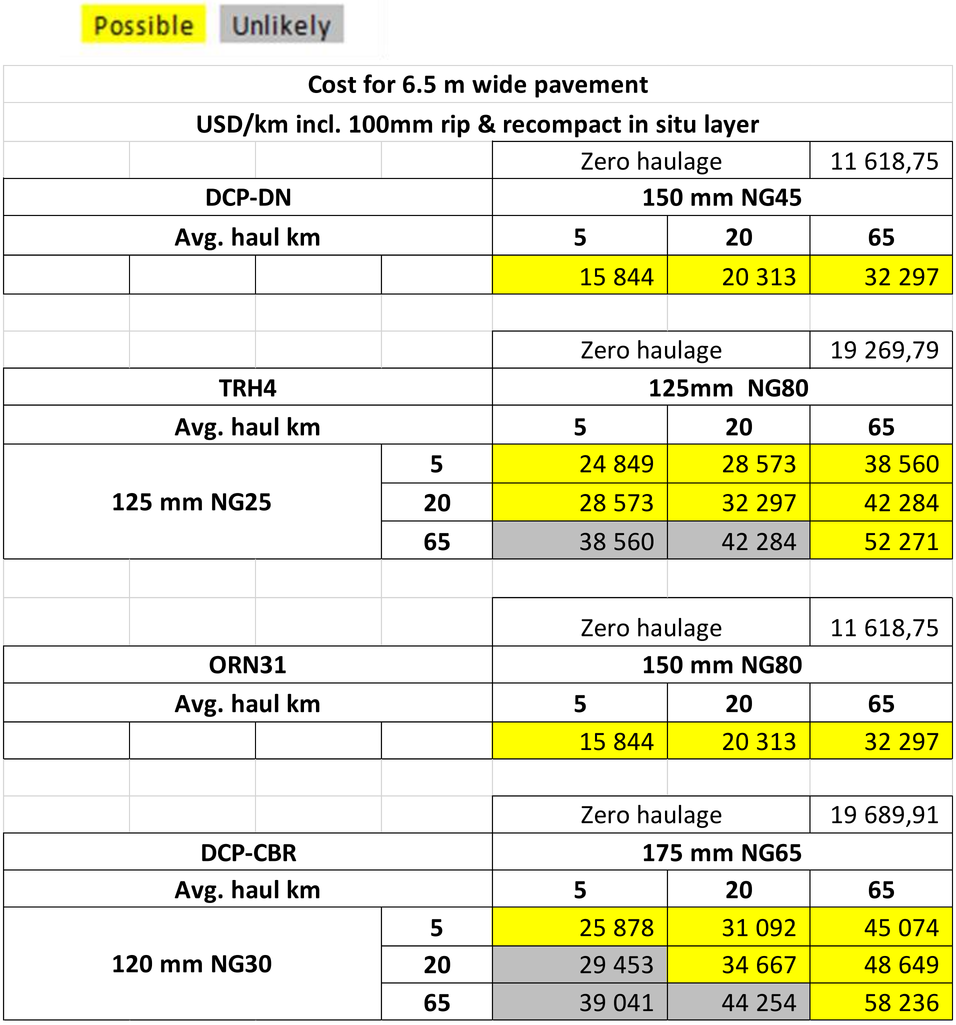
		Zero haulage		11 618,75
ORN31		**150 mm NG80**		
Avg. haul km		**5**	**20**	**65**
		15 844	20 313	32 297

		Zero haulage		18 196,10
DCP-CBR		**150 mm NG80**		
Avg. haul km		**5**	**20**	**65**
120 mm NG30	**5**	41 592	48 742	67 917
	20	48742,20	55 892	75 067
	65	67917,20	75067,20	94 242



Malawi: Salima: Battalion - Lifuwu (T357) km 0.00 to km 7.00

Site Avg. DN	DCP-DN	TRH4	ORN31	DCP-CBR
				New base 175 mm
		New base 125 mm CBR_{soaked}= 80 NG80		CBR_{soaked}= 65 NG65
	New base 150 mm DN= 3.2 CBR_{soaked}= 82 NG80	New subbase 125 mm CBR_{soaked}= 25 NG25	New base 150 mm CBR_{soaked}= 80 NG80	New subbase 120 mm CBR_{soaked}= 30 NG30
150 mm	150 mm	150 mm	150 mm	150 mm
DN= 4.09	DN(80P)= 4.54	DN (90P)= 4.78	DN(90P)= 4.78	DN= 4.09
Moist. Ratio= 0.75	CBR_{OMC}= 60	$CBR_{0.75\ OMC}$= 56	$CBR_{0.75\ OMC}$= 58	$CBR_{0.75\ OMC}$= 68
CBR_{KLEIN} = 69		CBR_{soaked}= 9	CBR_{omc}= 32	CBR_{soaked}= 14
CBR_{Soaked} = 15		Subgrade S4	Subgrade S6	Subgrade S4
	R&R 100mm	R&R 100mm	R&R 100mm	R&R 100mm



Possible Unlikely

Cost for 6.5 m wide pavement

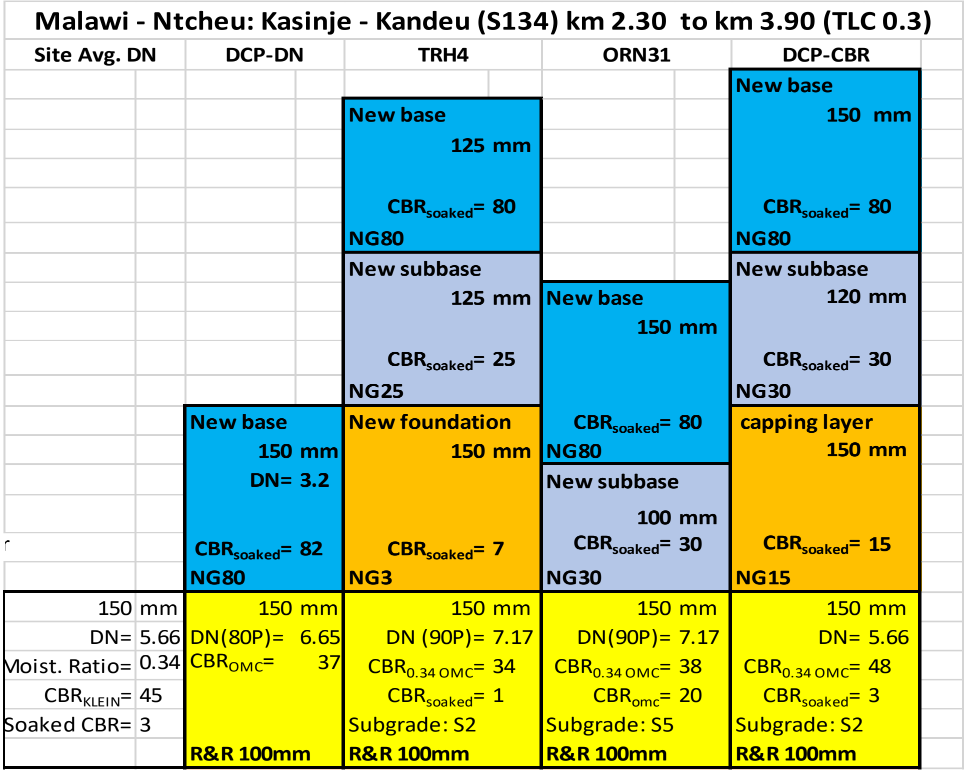
USD/km incl. 100mm rip & recompact in situ layer

		Zero haulage		11 618,75
DCP-DN		**150 mm NG45**		
Avg. haul km		**5**	**20**	**65**
		15 844	20 313	32 297

		Zero haulage		19 269,79
TRH4		**125mm NG80**		
Avg. haul km		**5**	**20**	**65**
125 mm NG25	**5**	24 849	28 573	38 560
	20	28 573	32 297	42 284
	65	38 560	42 284	52 271

		Zero haulage		11 618,75
ORN31		**150 mm NG80**		
Avg. haul km		**5**	**20**	**65**
		15 844	20 313	32 297

		Zero haulage		19 689,91
DCP-CBR		**175 mm NG65**		
Avg. haul km		**5**	**20**	**65**
120 mm NG30	**5**	25 878	31 092	45 074
	20	29 453	34 667	48 649
	65	39 041	44 254	58 236



Malawi - Ntcheu: Kasinje - Kandeu (S134) km 2.30 to km 3.90 (TLC 0.3)

Site Avg. DN	DCP-DN	TRH4	ORN31	DCP-CBR
		New base 125 mm CBR_{soaked}= 80 NG80		New base 150 mm CBR_{soaked}= 80 NG80
		New subbase 125 mm CBR_{soaked}= 25 NG25	New base 150 mm CBR_{soaked}= 80 NG80	New subbase 120 mm CBR_{soaked}= 30 NG30
	New base 150 mm DN= 3.2 CBR_{soaked}= 82 NG80	New foundation 150 mm CBR_{soaked}= 7 NG3	New subbase 100 mm CBR_{soaked}= 30 NG30	capping layer 150 mm CBR_{soaked}= 15 NG15
150 mm DN= 5.66 Moist. Ratio= 0.34 CBR_{KLEIN}= 45 Soaked CBR= 3	150 mm DN(80P)= 6.65 CBR_{OMC}= 37 R&R 100mm	150 mm DN (90P)= 7.17 $CBR_{0.34\ OMC}$= 34 CBR_{soaked}= 1 Subgrade: S2 R&R 100mm	150 mm DN(90P)= 7.17 $CBR_{0.34\ OMC}$= 38 CBR_{omc}= 20 Subgrade: S5 R&R 100mm	150 mm DN= 5.66 $CBR_{0.34\ OMC}$= 48 CBR_{soaked}= 3 Subgrade: S2 R&R 100mm

Possible Unlikely

Cost for 6.5 m wide pavement

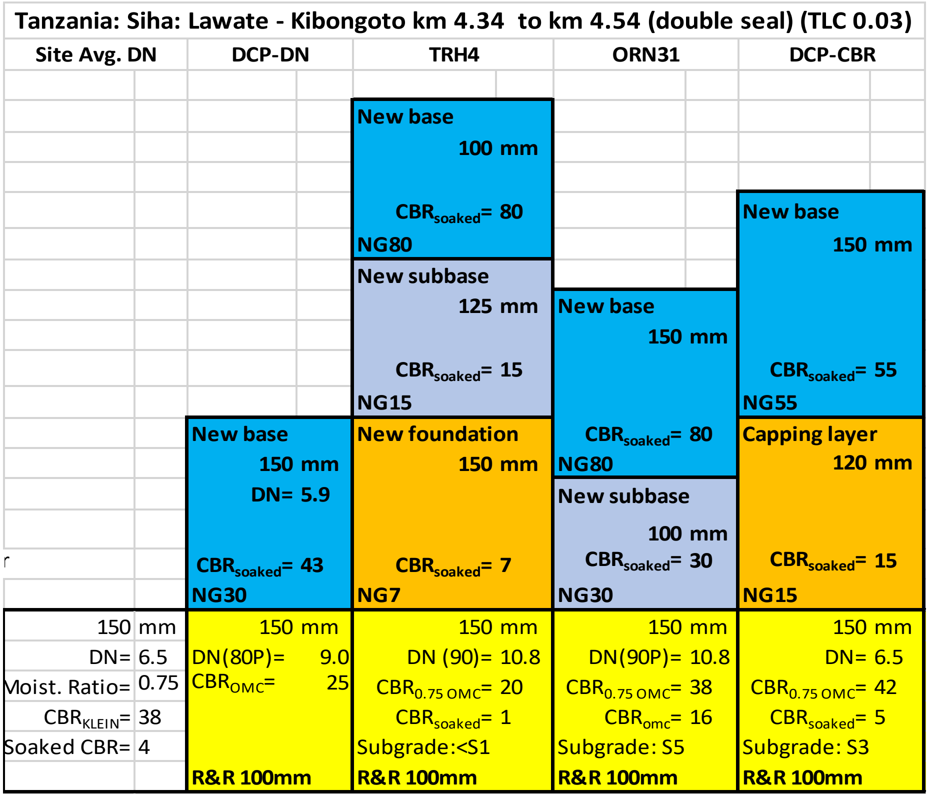
USD/km incl. 100mm rip & recompact in situ layer

				Zero haulage		11 618,75
DCP-DN				**150 mm NG80**		
Avg. haul km				**5**	**20**	**65**
				15 844	20 313	32 297

				Zero haulage		27 394,79
		TRH4		**125mm NG80**		
		Avg. haul km		**5**	**20**	**65**
150 mm NG3	**5**	**125 mm NG25**	**5**	35 005	38 729	48 716
			20	38 729	42 453	52 440
			65	48 716	52 440	62 427
	20	**125 mm NG25**	**5**	39 474	43 198	53 185
			20	43 198	46 922	56 909
			65	53 185	56 909	66 896
	65	**125 mm NG25**	**5**	51 458	55 182	65 169
			20	55 182	58 906	68 893
			65	65 169	68 893	78 880

			Zero haulage		19 337,50
ORN31			**150 mm NG80**		
Avg. haul km			**5**	**20**	**65**
100 mm NG30		**5**	24 917	29 385	41 370
		20	27895,83	32 365	44 349
		65	35885,42	40354,17	52 339

				Zero haulage		28 904,20
DCP-CBR				**150 mm NG80**		
Avg. haul km				**5**	**20**	**65**
150 mm NG15	**5**	**120 mm NG30**	**5**	38 248	42 717	54 701
			20	41822,95	46 292	58 276
			65	51410,45	55879,20	67 864
	20	**120 mm NG30**	**5**	42 717	47 185	59 170
			20	46291,70	50 760	62 745
			65	55879,20	60347,95	72332,33
	65	**120 mm NG30**	**5**	54701,08	59169,83	71 154
			20	58276,08	62744,83	74 729
			65	67863,58	72332,33	84316,70



Tanzania: Siha: Lawate - Kibongoto km 4.34 to km 4.54 (double seal) (TLC 0.03)

Site Avg. DN	DCP-DN	TRH4	ORN31	DCP-CBR
		New base 100 mm CBR_{soaked}= 80 NG80		
		New subbase 125 mm CBR_{soaked}= 15 NG15	New base 150 mm CBR_{soaked}= 80 NG80	New base 150 mm CBR_{soaked}= 55 NG55
	New base 150 mm DN= 5.9 CBR_{soaked}= 43 NG30	New foundation 150 mm CBR_{soaked}= 7 NG7	New subbase 100 mm CBR_{soaked}= 30 NG30	Capping layer 120 mm CBR_{soaked}= 15 NG15
150 mm DN= 6.5 oist. Ratio= 0.75 CBR_{KLEIN}= 38 oaked CBR= 4	150 mm DN(80P)= 9.0 CBR_{OMC}= 25 R&R 100mm	150 mm DN (90)= 10.8 $CBR_{0.75\ OMC}$= 20 CBR_{soaked}= 1 Subgrade:<S1 R&R 100mm	150 mm DN(90P)= 10.8 $CBR_{0.75\ OMC}$= 38 CBR_{omc}= 16 Subgrade: S5 R&R 100mm	150 mm DN= 6.5 $CBR_{0.75\ OMC}$= 42 CBR_{soaked}= 5 Subgrade: S3 R&R 100mm

🟨 Possible ▨ Unlikely

Cost for 6.5 m wide pavement

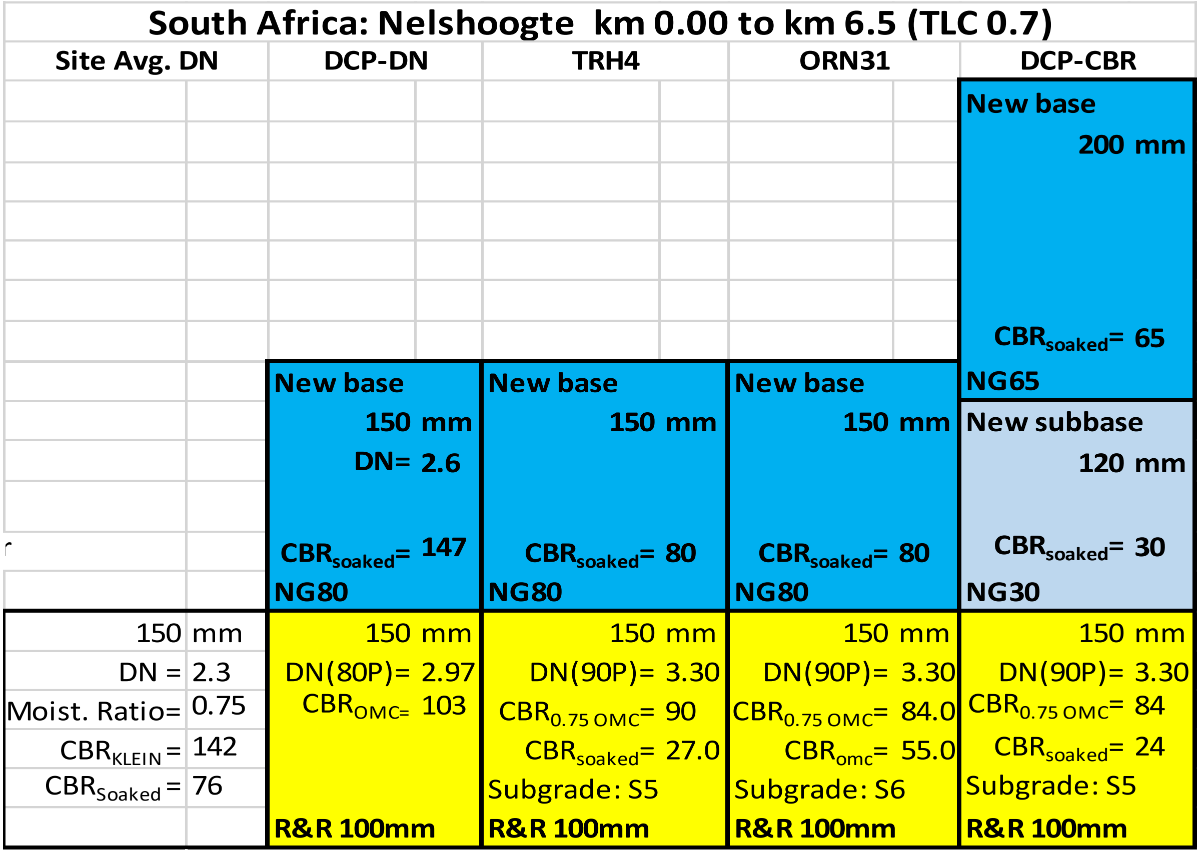
USD/km incl. 100mm rip & recompact in situ layer

		Zero haulage		9 181,25
DCP-DN		**150 mmNG30**		
Avg. haul km		**5**	**20**	**65**
		13 406	17 875	29 859

				Zero haulage		26 717,71
		TRH4		**10mm NG80**		
		Avg. haul km		**5**	**20**	**65**
150 mm NG7	**5**	**125 mm NG15**	**5**	33 990	36 969	44 958
			20	37 714	40 693	48 682
			65	47 701	50 680	58 669
	20	**125 mm NG15**	**5**	38 458	41 438	49 427
			20	42 182	45 161	53 151
			65	52 169	55 148	63 138
	65	**125 mm NG15**	**5**	50 443	53 422	61 411
			20	54 167	57 146	65 135
			65	64 154	67 133	75 122

		Zero haulage		19 337,50
ORN31		**150 mm NG80**		
Avg. haul km		**5**	**20**	**65**
100 mm NG30	**5**	24 917	29 385	41 370
	20	27895,83	32 365	44 349
	65	35885,42	40354,17	52 339

		Zero haulage		18 771,51
DCP-CBR		**150 mm NG55**		
Avg. haul km		**5**	**20**	**65**
120 mm NG15	**5**	24 622	29 090	41 075
	20	28196,51	32 665	44 650
	65	37784,01	42252,76	54 237



South Africa: Nelshoogte km 0.00 to km 6.5 (TLC 0.7)

Site Avg. DN		DCP-DN	TRH4	ORN31	DCP-CBR
					New base **200 mm** **CBR_{soaked}= 65** **NG65**
		New base **150 mm** **DN= 2.6** **CBR_{soaked}= 147** **NG80**	**New base** **150 mm** **CBR_{soaked}= 80** **NG80**	**New base** **150 mm** **CBR_{soaked}= 80** **NG80**	**New subbase** **120 mm** **CBR_{soaked}= 30** **NG30**
150	mm	150 mm	150 mm	150 mm	150 mm
DN =	2.3	DN(80P)= 2.97	DN(90P)= 3.30	DN(90P)= 3.30	DN(90P)= 3.30
Moist. Ratio=	0.75	$CBR_{OMC=}$ 103	$CBR_{0.75\ OMC}$= 90	$CBR_{0.75\ OMC}$= 84.0	$CBR_{0.75\ OMC}$= 84
CBR_{KLEIN} =	142		CBR_{soaked}= 27.0	CBR_{omc}= 55.0	CBR_{soaked}= 24
CBR_{Soaked} =	76		Subgrade: S5	Subgrade: S6	Subgrade: S5
		R&R 100mm	**R&R 100mm**	**R&R 100mm**	**R&R 100mm**

Possible Unlikely

Cost for 6.5 m wide pavement				
USD/km incl. 100mm rip & recompact in situ layer				
		Zero haulage		11 618,75
DCP-DN		**150 mm NG45**		
Avg. haul km		**5**	**20**	**65**
		15 844	20 313	32 297
		Zero haulage		11 618,75
TRH4		**150 mm NG80**		
Avg. haul km		**5**	**20**	**65**
		15 844	20 313	32 297
		Zero haulage		11 618,75
ORN31		**150 mm NG80**		
Avg. haul km		**5**	**20**	**65**
		15 844	20 313	32 297
		Zero haulage		19 919,03
DCP-CBR		**200 mm NG65**		
Avg. haul km		**5**	**20**	**65**
120 mm NG30	**5**	26 446	32 404	48 384
	20	30 021	35 979	51 959
	65	39 609	45 567	61 546