A DECISION-SUPPORT PROCESS FOR THE UPGRADING OF GRAVEL ROADS IN THE WESTERN CAPE PROVINCE

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ABSTRACT

A Decision-Support Process for the upgrading of roads in the Western Cape has become essential given the scarcity of suitable gravel materials, road infrastructure backlog conditions and budgetary constraints.

The Western Cape Government Department of Transport is custodian of around 10 400 km of gravel roads within its borders. These roads are located over 5 Districts each with disparate traffic, geological, road condition and topographic challenges. Guided by its mission "to develop and maintain appropriate infrastructure and related services for sustainable economic development, which generates growth in jobs and facilitates empowerment and opportunity", the Department is compelled to provide sound infrastructure delivery processes in managing the asset life-cycle, which ranges from project-identification, prioritization, planning, design, implementation and maintenance- all within a sound reporting and monitoring framework.

This paper is guided by the strategic objectives of the road asset within the provisions of the Western Cape Spatial Development and Provincial Land Transport Frameworks. It looks at the issue of limited resources and the need for its optimisation within an asset- management and lifecycle-costing context. Furthermore, it provides a description of the provincial road network and its traffic conditions within a context of economic growth. This leads to a description of the Deighton Total Infrastructure Management System, which is used to develop the Road Network Preservation Model for determining the sustainability of the roads asset. It summarises the impacts of the preservation model across all road programmes and highlights the current trends specific to gravel road maintenance and gravel upgrade programs. It then develops a range of funding and program scenarios in a quest to optimise asset life within constrained resources- such as funding.

ABBREVIATIONS AND DEFINITIONS

2016/17 FY	Financial Years 2016 to 2017 as per the DTPW calendar commencing 01st April 2016 and ending 31st March 2017
Branch	The Road Network Management Branch of the DTPW
CKDM	Central Karoo DM
CWDM	Cape Winelands DM
DM	District Municipality
DRE	District Roads Engineer
dTIMS	Deighton Associates life cycle cost optimisation software. It is used to predict the future consequences of maintenance and funding policies
DTPW	Department of Transport and Public Works of the Western Cape Government
EDM	Eden DM
GRMMS	Gravel Road Maintenance Management System
HDM-4	Highway Development and Management system.
HDM-III and HDM-4	are software and models used to investigate road transport infrastructure
Intervention	For unpaved roads the objective is to maintain all gravel roads with gravel wearing course
Budget	material and roads carrying less than 50 vehicles per day with spot re-gravelling.
JPI	Joint Planning Initiative
MTEF	Medium Term Expenditure framework
NCN	Network Condition Number. A measure of the visual condition of the entire road network. See TRH22, 1994, 'Pavement Management Systems', CSRA, for further details.
ODM	Overberg DM
RNIS	Road Network Information System of the Provincial Roads and Transport Management Branch of the Western Cape Province (June 2016)
SMCA	Spatial Multi-criteria analyses
Technical	A theoretical budget scenario preventing all roads from deteriorating beyond the treatment
Needs Budget	intervention thresholds
VCI	Visual Condition Index as determined using the TMH 9 Guideline for the assessment of gravel roads
VOC	Vehicle Operating Cost
WCDM	West Coast DM
WCG	Western Cape Government

INTRODUCTION

The WCG DTPW manages over 10 000 km of proclaimed gravel roads. However, with a constrained fiscal budget, and an ageing road asset, there are growing backlogs experienced on gravel road network. This paper seeks to contextualise the extent of the problem and to present the current decision-support process for the upgrading of gravel roads based on asset preservation and resource optimisation. It also presents some additional decision-support criteria needed to address the disparities evident in the spatial characteristics of the network.

The WCG Proclaimed Road Network

Figure 1 indicates the extent of paved and gravel roads per road category, which are managed by the DTPW. There are around 6 370 km of paved road network and 10 374 km of mainly class 3 and 4 gravelled roads. In addition, there over 15 000 km of minor roads (refer Table 2), mainly in the form of ungraded tracks, which provide access to private farms and

FIGURE 1 Paved and Unpaved Road Network lengths per road class

	Paved, carriageway km	Paved Class %	Unpaved, centreline km	Unpaved Class %
Class 1	179.60	3%	0.00	0%
Class 2	2675.90	42%	131.24	1%
Class 3	2346.17	37%	1786.22	17%
Class 4	1125.88	18%	8147.95	79%
Class 5	41.19	1%	308.12	3%
Total	6368.74	100%	10373.53	100%

Gravel Road lengths (km) across DMs						
DM	Length in km					
	TR	MR	DR	Minor Rd	Total	Percent
Cape Winelands	0.00	234.41	1172.59	1766.34	2908.82	11%
Central Karoo	68.07	629.13	1676.80	3890.42	6266.79	25%
Eden	63.17	455.47	2510.36	2328.59	5341.81	21%
Overberg	0.00	128.93	1241.07	1502.06	2837.79	11%
West Coast	0.00	424.75	1747.25	5896.06	7926.16	31%
City of Cape Town	0.00	0.00	9.72	14.53	24.25	0%
Total for Province	**131.24**	**1872.69**	**8357.79**	**15398.00**	**25305.62**	**100%**

TABLE 1 WCG Gravel Road lengths per DM

public servitudes. Although these minor roads appear on the asset base, they do not however form part of the annual budget priorities.

The unpaved road network is classified mainly as Class 4 rural collectors or Divisional Roads which provide a road user access function (RCAM 2012), and make up 79% of the gravelled network. The higher order Class 3 Provincial Trunk and Main Roads make up 17% of the gravelled road network, and provide a mobility function for the road user.

The gravelled network only carries 4% of the total provincial traffic, namely 330 million vehicle-kilometres per year-

- 93% of the gravelled roads carry less than 250 vehicles per day.
- 1% of the gravelled roads carry over 500 vehicles per day

There are thus less than 150 km of unpaved roads that carry more than 500 vehicles per day, and another 600 km that carry between 250 and 500 vehicles per day.

The WCG gravelled road lengths and visual condition indices (VCIs) were measured and derived during the annual visual condition assessments (August 2015/16 financial year) and are recorded for each District Municipality (DM) in Tables 1 and 2 respectively.

Because of its proximity to the City functional area, the CWDM has the joint-lowest share of the unpaved network (i.e. 11%). However, it has the highest share (61%) of gravel roads in the poor to very poor condition category. Noticeably, rural CKDM, which has the second highest share of the unpaved network (i.e. 25%), has (second to CWDM) a very high share of roads in the poor to very poor condition category (43%)- i.e. there is a comparatively low overall investment in the annual CKDM road programme. Of perhaps similarly concern are the gravel roads in the WCDM- it has the highest share of network (31%), but a comparatively low share of roads in the good to very good category. Beside the City, the ODM and WCDM both lead in the highest share of gravel network in the fair category, i.e. 60-70%. Of concern however, is that most of these roads could be bordering on poor given the general decline in conditions.

Nearly 40% of the gravel road network is in a poor to very poor condition and only 13 % are in a good to very good condition. The trend over the last 10 years (RAMP 2016) shows an increase in the amount of roads in a very poor condition and an average drop in the good to very good categories since 2006.

Table 3 provides a graphical view of the defects on the WCG network. Stoniness fixed is the predominant defect followed by potholes and corrugations. These three defects are the major contributors to roughness on the network. On the poor to very poor part of the network, corrugations are more pronounced than potholes. The level of roughness varies from 7.5 to 15 IRI for a high to very low level of service. These levels, in turn correspond to safety levels of 3 to 4 respectively, as measured in TRH 12. A more detailed investigation is however required to drive motivation for road improvements from a safety perspective.

NETWORK LIFECYCLE OPTIMISATION (DTIMS)

The Branch uses the dTims lifecycle costing software model to optimise its maintenance and reconstruction programmes to determine the preservation priorities of the road asset under a constrained budget. The various

TABLE 2 WCG DTPW Gravel Road condition lengths per DM

Condition distribution per DM for unpaved roads in the Western Cape Province in 2015 excluding Minor Roads									
DM	Length (km)								
	Very Poor	Poor	Fair	Good	Very Good	Total	Vpoor to Poor	Good to vGood	Fair
City of Cape Town	0	3	12	0	0	15	20%	0%	80%
Cape Winelands	232	627	453	85	10	1407	61%	7%	32%
Eden	202	960	1237	613	17	3029	38%	21%	41%
Overberg	6	268	849	223	24	1370	20%	18%	62%
Central Karoo	153	862	1135	214	10	2374	43%	9%	48%
West Coast	22	448	1570	132	0	2172	22%	6%	72%
WC Province	**615**	**3168**	**5256**	**1267**	**61**	**10367**	**36%**	**13%**	**51%**
Percentage	6%	31%	51%	12%	1%	100%			

Defect Type	Total Network		Part of the network that is in poor or very poor condition	
	km	%	km	%
Corrugations	1678.03	**15.5**	529.99	**4.9**
Dust	496.96	4.6	0.00	0.00
Erosion: Longitudinal	196.03	1.8	55.65	0.5
Erosion: Transverse	277.26	2.6	85.67	0.8
Loose material	95.16	0.9	19.3	0.2
Potholes	1716.58	**15.9**	268.03	**2.5**
Rutting	62.93	0.6	13.31	0.1
Stoniness fixed	6086.92	**56.3**	2895.87	**26.8**
Stoniness loose	207.04	1.9	33.71	0.3

TABLE 3 Gravel Road Defect types

data information systems used to drive dTims is shown in Figure 2. At the strategic level, the systems used for resource allocation are housed in the road network information system (RNIS). These are comprised of pavement (PMS), gravel road (GRMS), bridge (BMS), and economic costs (HDM4) information. These systems drive the dTims model to derive the optimised materials information (MIMS) and gravel road maintenance management (GRMMS) systems to identify the delivery programmes and candidate projects at a network level within the constraints of the MTEF Budget.

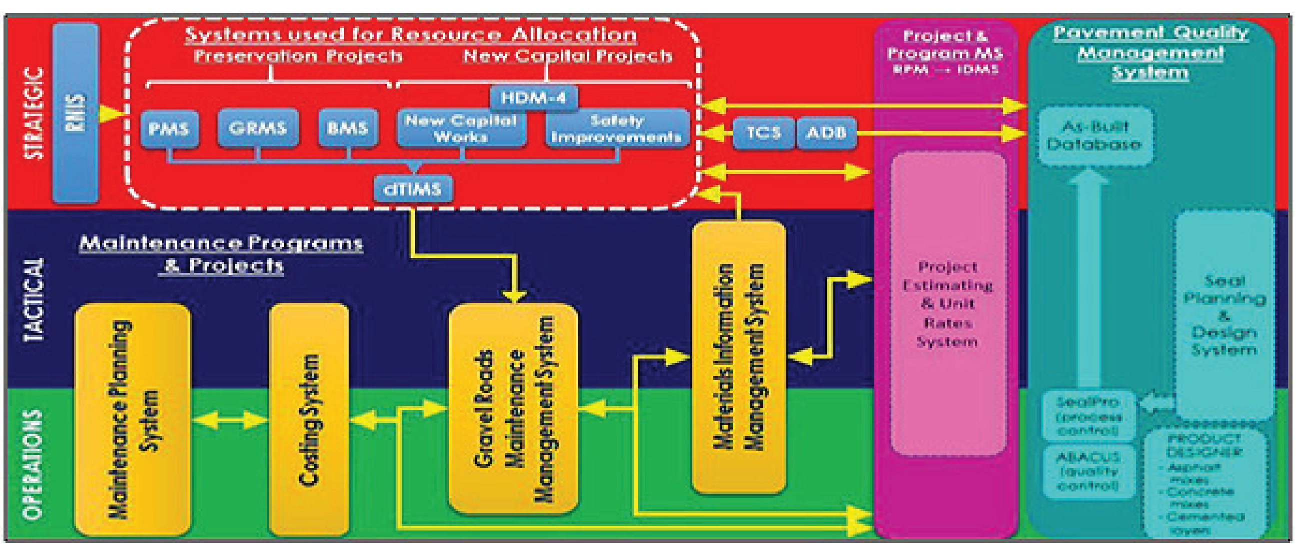
Budget Shortfall

The DTPW runs its dTims optimisation analyses every two years to optimise its road programmes within the available MTEF budget. The results contained in this paper were determined from the 2015/16 run. The current MTEF budget-shortfall (backlogs) as determined within the prioritisation model is shown in Table 4 (RAMP 2016). As can be seen, there is a shortfall (backlog) of 8-14 billion rand for the entire paved and gravel network on the MTEF budget. The unusual jump in shortfall between 2014/15 and 2015/16 is accounted for by the new TMH 22 definition for rehabilitation levels of service, which is the 90-percentile roughness value as compared to the previous definition which used the average roughness value.

The dTims objective function in the Intervention Budget scenario functions on the area-under-the-road condition-deterioration curve (AUC) method. It uses economic weighting to incorporate road length, economic activity and traffic. Compliance with intervention levels is phased in over 10 years for unpaved roads. Whilst for the Technical Needs Budget scenario, preventive maintenance, and upgrading, are adhered to as soon as the need arises, without regard to cost- i.e. it assumes an unconstrained budget. The result of this maintenance scenario is minimised transport costs and roads that are preserved in an optimal condition. The objectives of the Technical Needs Budget scenario are:

- To upgrade unpaved roads to paved standards which display justifiable economic benefits

FIGURE 2 WCG Road Data Information Systems used to drive the dTims Model



Year	Value (Rand million)	Value adjusted for 2015 Rands (Rand million)	Budget shortfall as a proportion of annual budget[1] (budget years)
1999	680	2084	6.7
2000	1230	3575	9.7
2001	1169	2799	4.2
2003	2140	5124	6.7
2005	2573	5565	4.8
2007	3535	6935	6.8
2009	5465	8646	9.6
2012	7044	8915	6.9
2014	10124	11440	**7.9**
2016	21724	21724	**14.3**

Note1: the shortfall is determined by comparing the 2016/17 Provincial MTEF fund allocation to the 2016/17 need of the Technical Needs Budget.

TABLE 4 dTims total budget backlog (for paved, re-gravel and upgrading of gravel road programmes)

- To re-gravel unpaved roads that have insufficient gravel material
- To maintain an optimal road condition after the backlog has been cleared
- Compliance with intervention levels is achieved immediately.

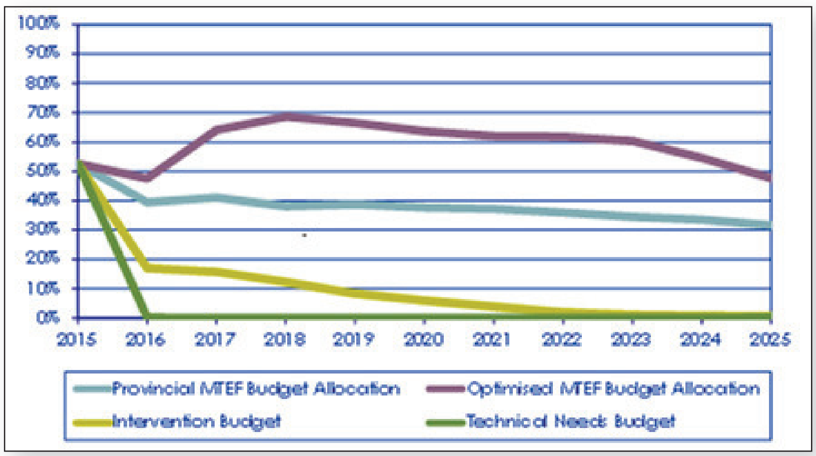


FIGURE 3 Baseline configuration – raw wastewater Activated Sludge system with SST/Membranes, surface aeration, and direct WAS discharge to sludge drying beds

Re-gravel backlog

The dTims model indicates a very high annualised need for the re-gravelling effort required, being in excess of 1 800 km for spot re-gravelling and more than 1 400 km for re-gravelling of the gravel wearing surfaces. This is directly related to the 37% of unpaved roads operating in a poor to very poor condition. For unpaved roads carrying more than 50 vehicles per day, the Intervention Budget has the objective to gradually re-gravel roads with inadequate gravel thicknesses. For unpaved roads carrying less than 50 vehicles per day, the maintenance invention of spot re-gravelling is used on roads with inadequate gravel thickness. An annualised expenditure of R505 million is required for re-gravel and spot re-gravel. There is a shortfall of R352 million per annum. The current maintenance levels for re-gravelling are around 100 to 200 km per annum. However the immediate need for re-gravelling (minimum intervention) is 4 400 km, with a year-on year average spot re-gravelling need of 1 800 km per annum. The network gravel thicknesses vary between 25 to 100 mm, with most of the network (87%) at less than 50mm and 72% at 0-25 mm thickness. It is has been at these levels since 2009. In terms of rideshare, 20% of passengers travel on good to very good gravel roads, 20% on poor to very poor and 60% on a fair gravel road condition.

Upgrade backlog (gravel roads to paved standards)

The proposed annualised funding level of the MTEF Budget for upgrades is approximately the same as the Intervention Budget. In the analysis of the Intervention Budget, approximately 100 km of unpaved roads were selected to be upgraded to paved standards. These all carry more than 400 vehicles per day. The cost for the upgrading is approximately R700 million that is scheduled at an average of R140 million per annum over the next five years. There is a shortfall of approximately R90 million per annum.

Figure 3 illustrates that the proportion of gravel road network not being able to meet the minimum intervention standards will be increasing year on year, if the current funding regime persists without intervention. Whilst it is not suggested that an upscale in upgrade effort can stay the backlog under the current resource constraints, there is however a need to drive the upgrade program by a sound capital investment process that is able to compete for additional funds. This must also ensure long term spatial planning goals are achieved in a region. (ARRB 2013)

Pass-ability of gravel roads

Pass-ability is a function of the shear strength of the top layer of the wearing course (TRH 20). With insufficient quantities of coarse gravel in the gravel layer and inadequate subgrade shear strength, pass-ability problems will occur. An average minimum gravel thickness of 50 mm ensures pass-ability and maintenance on unpaved roads. For dTims 2015, roads carrying less than 50 vehicles per day were not included as these roads

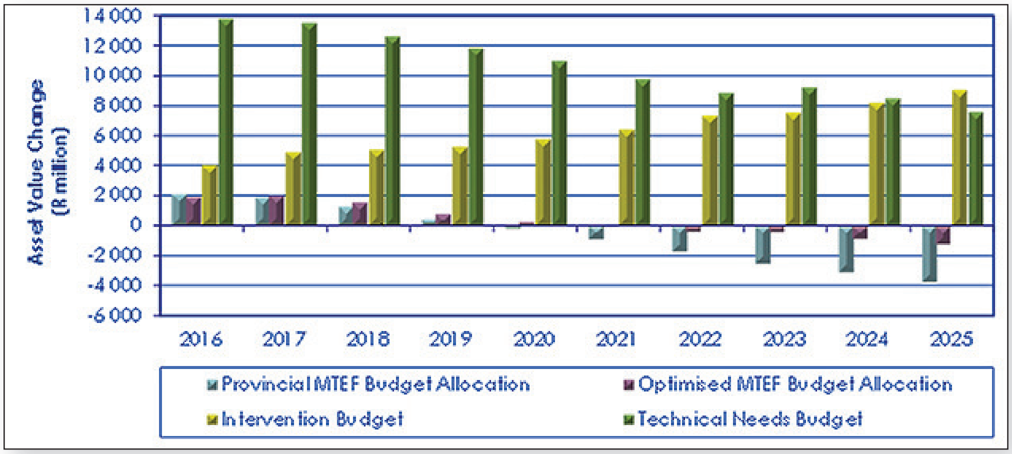


FIGURE 4 Improved Gravel Road Asset Value with various f

are not maintained with re-gravelling of the wearing courses and many of these roads operate with acceptable pass-ability. The results show that the predicted proportion of unpaved roads with traffic greater than 50 AADT operating on a gravel wearing course with less than 50 mm of gravel material is currently 44% (more than 4 500km). Earth roads are excluded from this calculation (RAMP 2016).

IMPACT OF IMPROVED BUDGET SCENARIOS

The current MTEF funding level of the province cannot lead to an increase in asset value for both paved and unpaved road networks. This is due to the ongoing deterioration of paved roads that contributes to more than 99% of the current total network asset value. According to the analysis results, both the Intervention Budget and Technical Needs Budget will lead to increased asset value levels because the overall gravel thickness is improving and paved roads are maintained at improved performance levels.

In an effort to maximise the long term effects on asset value, the Branch has optimised the MTEF budget to ensure maximum impact on the network sustainability. The results show that:

- Funding was reduced by 47% for upgrades of the unpaved roads
- Funding was increased by 14% for re-gravelling

Overall, the road network condition is very unlikely to improve under the current budget and unit rates, but the optimised allocation of funding assures a maximised economic return for the economic road network and a maximised preservation of the uneconomic roads.

The graph below illustrates the improvements on the projected 10-year asset value due to the optimised MTEF budget and the greater impacts should there be a marked increase to address technical needs (total cost of infrastructure needs per annum), or an intervention budget to maintain the threshold level standards (RAMP 2016).

Decision-support for Upgrading Gravel Roads

Whilst the re-gravelling concerns are largely managed in the Gravel Road Maintenance Management System (GRMMS), a business process is needed for the selection of upgrade projects on to the implementation programme. This, particularly, because it is a Capital Investment Programme and therefore could potentially compete for funding from additional sources. It should further seek to link the project identification phase with a process for project selection given the constrained resource environment sketched above. The current mechanisms of identifying upgrade projects are (refer Figure 5 below as well):

- A strategic gap analysis of the network to determine investment priorities;
- Using the dTims model, based on traffic volumes, average costs of maintenance and vehicle operating costs;
- The municipal Integrated Development Plans that provide transport sector needs and projects that the local municipalities have identified to promote development;
- Maintenance related upgrades identified by the DREs and DMs. These are sections of the network that are expensive to maintain due to, e.g. lack of suitable materials, geographical position in the network- there are natural materials occurring in an area, where these natural materials are more suited to layer works than gravel wearing course. This means that the haul distances for gravel maintenance or project pits become excessive;
- Donor funds from private developers, farmer forums and or special needs road-user groups. Here for instance, DM's in particular are often approached by farmers where they will supply materials or make substantial contributions, which raise their chances of the Branch reacting positively to their interest.

Once the relevant information has been gathered at the feasibility stage on all these sources of projects, they are analysed in HDM-4 for their economic viability. It is important to note that appropriate standards must be used for the solution to each upgrade. For example, highly trafficked roads would be upgraded to a normal class 4 cross-section, whereas maintenance related upgrades with low traffic would be upgraded to a much lower standard, both in terms of cross-section, alignment and pavement structure. In this case it is much more important to preserve the gravel on the road and reduce maintenance costs than to achieve a high level of service provided by a class 4 road.

To start the process, only the top two or three projects from each category that are potential upgrade candidates would be analysed in HDM-4 for each District Municipality (DM) area. As funds are limited, it is better to start on a few projects. The projects would then be optimised in HDM-4 across all DMs to produce a program of priority projects. The analysis in HDM-4 would preferably be done in the Branch, or by one expert consultant. The Branch has an internal (Risk Register) deadline to submit its Upgrade Strategy during this financial 2016/17.

Based on this, the DTPW Roads Branch has derived a Draft Gravel Road Upgrade Business Process as shown in Figure 5.

The Upgrade Priority List

The current Upgrade Priority List appears in Appendix A. It is based on a Present-Worth-of-Costs determination using the HDM4 functionality within DTIMs.

GAPS IN THE UPGRADE PROCESS

The current process does not consider the Gross Domestic Product affects due the percentage-share of goods transported on gravel roads. This would mainly be for break-bulk, agricultural, timber and steel products (Draft SA Freight Strategy 2015) transported on WCG roads. Neither are the needs of passenger movement (i.e. non-motorised transport and public transport) linked to the road condition categories. It is envisaged to update the dTims to include these statistics in future via a socio-economic objective function (RAMP 2016). This is of particular importance since the excess vehicle operating costs (VOCs) on all roads are 52% above the 3.1 IRI roughness index- these are classified as 'unnecessary user costs that could otherwise have been avoided had all roads been at

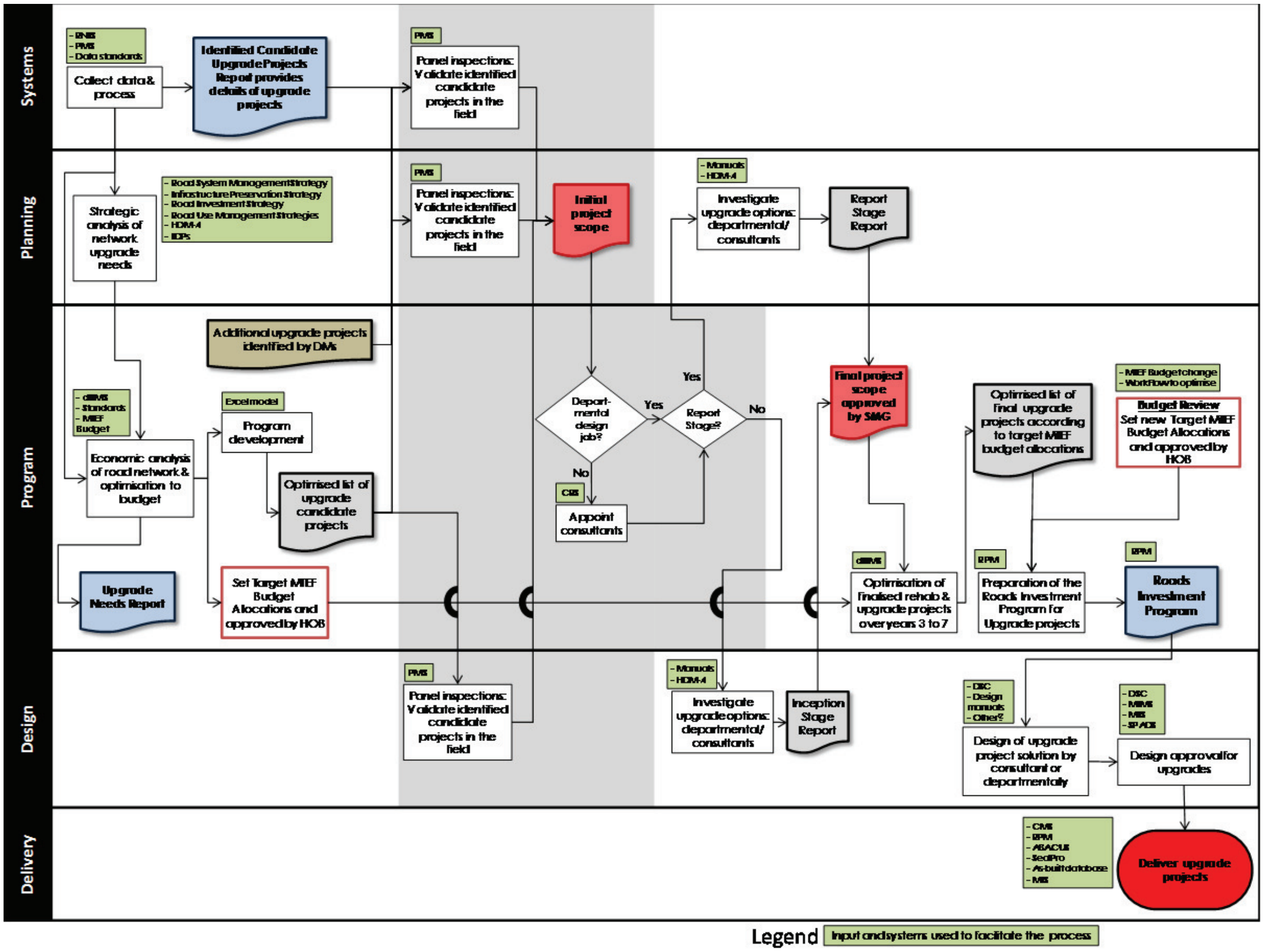


FIGURE 5 Draft Gravel Road Upgrade Business Process (WCG DTPW 2016)

the desired levels of ride-ability. The excess VOCs are around R 371 Million per million-vehicle kilometres on WCG roads.

Beside the re-gravel effort needed, some gravel roads do qualify for upgrading on an annual basis. Approximately 240 km of unpaved road currently have sufficient economic merit to be upgraded to paved standards. These roads all have traffic volumes in excess of 400 vehicles per day (AADT).

Further research indicates that the Australian Roads Research Board (ARRB 2009), in their 'Unsealed Roads Manual - Guide to Good Practice', developed key principles in applying economic evaluations as a method to justify the sealing (upgrading) of a road. The principles when applied, generally demonstrate as a rough guide that it may be difficult to justify sealing a road carrying less than 100 vehicles per day, whereas if the road is carrying over 250 vehicles per day it will probably be justified. In between the 100 and 250 vehicles per day is the 'grey area', where using additional guidelines may be of benefit in ranking these gravel roads based on economic and social values.

The Guide further indicates that a policy shift may be considered for the upgrade of rural (social) roads. This could mean that a policy of 150 vehicles per day is used as the primary criteria for prioritising the upgrading of rural gravel roads to a sealed surface. Where the gravel road does not meet the traffic volume criteria, it may have other benefits if sealed. The gravel road should therefore be further assessed on the following additional guidelines, in order of priority:

Reduced travel distance on gravel roads benefits;
• Crash history benefits;
• Economic improvements benefits; and
• Bus route and non-motorised transport improvement benefits.

Where a gravel road does not meet any of these warrants for improvement, residents, specific users or adjacent developments may be given the opportunity to consider paying for the improvement of a road through a special charge scheme or donor-fund, subject to approval by the planning authorities.

Shifts toward more comprehensive Integrated Planning

The Business Dictionary defines the discipline of Integrated Planning as a joint planning exercise that ensures the participation of all stakeholders and their affected state departments. Its objective is to examine all economic, social, and environmental costs and benefits, in order to determine the most appropriate option and to plan a suitable course of action.

In his 2015 Budget Speech, Minister Bredell indicates that over the past three years, the Western Cape has explored ways of fostering such planning and its implementation. This process has now evolved into a set of Joint Planning Initiatives (JPIs), and is set to enable the implementation of the National Development Plan on the one hand, and to enhance the development and implementation of the Provincial Strategic Plan on the other. The JPIs seek to identify a set of long-term strategic priorities which will jointly be implemented between the province and municipalities. It is an attempt to foster collaborative and deliberative planning where infrastructure planning happens in the context of other developmental needs in the Province (DLG, 2014). The planning practices across the tiers of government are thus becoming more integrated and more aligned toward national and regional long term priorities, keeping in mind that term transport infrastructure is an enabler of spatially-targeted development (Arup, 2008). It has thus become necessary that road planning must respond to the regional developmental needs in a spatial context (NLTA, 2009) and must be contained in the holistic assessment of land-based transport needs in order to optimize access and mobility for all potential users.

The road and transport investment solution will thus need to assume a more complex and integrated approach. This may require the need for the development of a decision-support tool to ensure a sound approach toward investment, which may take in to account the spatial considerations for optimising road alignment selection for long term regional benefits (Journal for Transport Geography, 2009)

Regional characteristics

The WC Spatial Development Framework (SDF) and the WC Provincial Land Transport Framework, both encourage a strategic thrust toward spatial equity. There is a long term need for correlating growth town potential with people movement. This strategic thrust is articulated in the WCG Strategic Goal 4: 'Spatial Alignment'.

Table 5 illustrates the relationship between gravel road share, road class and road conditions across DMs as provided from the data in Tables 1 and 2. This indicates-

- WC, CK and Eden DMs have a high to medium share of the gravel road network
- These three DMs also have the greatest share of class 2 and 3 (mobility routes) in the WC
- Despite this, the CK and Eden also have the highest share of gravel roads in a poor to very poor condition

Furthermore, the administrative centres of the WC, CK and Eden are the most remote from the City functional area, and have the highest share of network budget underinvestment. This is measured as a ratio between the fair to very good network percent over their share of gravel roads on the entire WC network.

The dTims model is more recently (2016) being modified to include a socio-economic objective function. It is intended that this function will take in to account these regional characteristics to drive upgrade priorities.

Recent work at the University of Cape Town (UCT), 2014

A DTPW pilot study with the Cederberg and Swartland Municipalities was conducted in 2014 led by the Department of Civil Engineering of the University of Cape Town (UCT) to foster the idea of a Spatial Multi-criteria Analyses (SMCA) for the upgrading of gravel roads. The following criteria were identified in the study:

- **Materials availability and proximity for upgrading and gravelling.** This would inform the upgrade potential and the frequency for re-graveling. The better the material-grading, the less likely to be considered for upgrade as faster speeds could be attained on gravel roads with good grading;
- **Development potential.** The closer the road is to an urban or town growth environment, the more reason to upgrade. This is linked to population size, access to public amenities, socio-political drive and traffic growth generation- particularly with high-disproportionate heavy vehicle growth;
- **Land use and topography.** Steep and undulating topography would incur more cost to upgrade due to critical infrastructure requirements such as bridges, culverts and pipelines, whilst agricultural or conserved land may trigger a higher potential for upgrade given the scarcity of suitable land for road building. Heritage and tourism corridors may trigger a higher sensitivity due to the need for specialist and environment impact assessments;
- **Weather.** Wet conditions would trigger a greater need to upgrade, whilst very dry conditions evoke difficult grading and more dust nuisance with respect to crops and visibility under heavy traffic.

These criteria were subsequently weighted in terms of their upgrade priority potential and used in a GIS interface of the study area to determine the upgrade potential of various mutually exclusive gravel road sections in the region.

CONCLUSIONS AND RECOMMENDATIONS

Whilst the WCG has an effective asset management system which provides extensive network condition data as a basis for optimising its road preservation programmes, more criteria are needed for improving gravel road upgrade investments in a resource constrained environment. It is proposed that various such criteria be developed within a joint planning environment to achieve this. The criteria emerging in this paper include-

- Availability of donor funding sources to drive upgrade potential;
- The portions of road which carry more than 400 vehicles per day and which are impassable;
- Which of the 150 km mobility routes have the highest public benefit and how will that value be captured and managed?;
- Which of the 600 km of access roads have the highest road side development contribution, and how will this be managed?;
- The regional under-investment disparities need to be weighed (e.g. GDP and condition/extent levels);
- More investigation into IRI levels across the network is needed to improve safety thresholds;

TABLE 5 Spatial relationship between length, class and gravel road conditions

			Share of gravel netw	High	High	Medium	Low	Low	very Low
Percent	Km	AADT	Rd class %split	WC	CK	Eden	Overberg	CW	CoCT
93%	9648	0-250	4	20	21	32	15	11	0
6%	622	250-500	3+4	21	24	30	14	12	0
1%	104	500-	2	0	52	48	0	0	0
100%	10374	km	Rd VCI %split	WC	CK	Eden	Overberg	CW	CoCT
			vpoor-poor	22	43	38	20	61	20
			fair-good	78	57	62	80	38	80

- A policy view is needed in addressing roads with 100-250 vehicles per day;
- The benefits of reduced travel distances on gravel networks need to be quantified with each candidate upgrade project. These should include passenger movement and crash reduction benefits;
- The recent UCT pilot study work should be integrated;
- The possible effects of optimising administrative centre locations or improving proximity to centralised resources.

It is intended to include the effects of these criteria in the future dTims objective functions.

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Appendix A: Prioritised list of Gravel Road Upgrade Projects 2016

Deliverable Type	Road Number (Structure Number)	Start km	End km	Project	Commencement Date	Completion Date	PV Cost of project (Rand)	PV benefit (Rand / km)	Current Project State
Upgrade Road, Gravel	DR01001	3.64	7.69	ODM/2016/IMMS 7002 - Upgrade on DR1001 Hangklip (3.64 - 7.69)km	01-Apr-18	29-Mar-19	28 548 450	538 096	Approved
Upgrade Road, Gravel	DR01094	0	4.62	C0850: Upgrade Gravel road DR1094 (Sandringham Road) from km 0.00 - 4.62	05-Dec-16	11-Dec-17	32 566 380	468 436	Design
Upgrade Road, Gravel	DR01103	0	3.88	C0850.01: Upgrade DR1103 from km 0 to km 3.88- Simonsvlei	09-Oct-18	14-Oct-19	27 350 120	596 454	Design
Upgrade Road, Gravel	DR01123	12.25	22.15	C1005: Upgrade DR01123 between Perdeberg & Klipheuwel	03-Apr-16	12-Jul-17	69 785 100	480 975	Contract Awarded
Upgrade Road, Gravel	DR01131	18.5	22.5	CWDM/2017/IMMS 8007 - Upgrade on DR1131 (18.50 - 22.50)km Haaskraal	01-May-17	03-Apr-18	28 196 000	673 536	Design
Upgrade Road, Gravel	DR01154	0.79	4.32	CWDM/2019/IMMS 8010 - Upgrade on DR1154 (0.79 - 4.32)km Zonwasdrift	01-Mar-20	31-Dec-20	24 882 970	334 141	Approved
Upgrade Road, Gravel	DR01173	0.41	1.04	WCDM/2016/IMMS 10009 - Upgrade on DR1173 (km 0.41 - 1.04)	23-Jan-17	21-Feb-17	4 440 870	336 772	Approved
Upgrade Road, Gravel	DR01221	0.44	1.3	ODM/2019/IMMS 7005/3005 - Rehab and Upgrade on DR1221 Bredarsdorp Golf Course (0.00 - 0.44)km (0.44 - 1.30)km	01-Apr-19	30-Mar-20	6 062 140	379 089	Envisaged
Upgrade Road, Gravel	DR01223	0	9.26	C1006: Upgrade DR01223 between Bredasdorp & Malgas	30-Apr-19	27-Jan-20	65 273 740	291 688	Design
Upgrade Road, Gravel	DR01239	0.14	1.7	ODM/2016/IMMS 7001 - Upgrade on DR1239 Camphill (0.14 - 1.70)km	15-Apr-16	20-Jul-17	10 996 440	340 355	Design
Upgrade Road, Gravel	DR01263	0	5.3	C0884.04: Upgrade DR1263 - Slangrivier/Heidelberg	20-Jan-20	27-Jul-20	37 359 700	220 175	On Hold
Upgrade Road, Gravel	DR01284	0.89	3.7	ODM/2019/IMMS 7004/3004 - Rehab and Upgrade on DR1284 Klipheuwel (0.00 - 0.89)km (0.89 - 3.70)km	01-Apr-19	30-Mar-20	19 807 690	660 998	Approved
Upgrade Road, Gravel	DR01318	0.19	3.65	ODM/2016/IMMS 7000 - Upgrade on DR1318 Olivedale (0.19 - 3.65)km	01-Apr-16	06-Jul-17	24 389 540	356 820	Under construction
Upgrade Road, Gravel	DR01320	6.21	9.53	ODM/2017/IMMS 7003 - Upgrade on DR1320 Graymead (6.21 - 9.53)km	01-Apr-17	30-Mar-18	23 402 680	597 426	Approved
Upgrade Road, Gravel	DR01337	0	5.9	CWDM/2018/IMMS 8009 - Upgrade on DR1337 (0.00 - 5.90)km Wansbek	01-Apr-18	04-Mar-19	41 589 100	145 115	Approved
Upgrade Road, Gravel	DR01364	4.33	10.44	CWDM/2019/IMMS 8008 - Upgrade on DR1364 (4.33 - 10.44)km Goree Riverside	01-Mar-19	04-Mar-20	43 069 390	298 237	Approved
Upgrade Road, Gravel	DR01399	0.23	0.97	CWDM/2016/IMMS 8005 - Upgrade on DR1399 (0.23 - 0.97)km Die Straat	01-Sep-16	01-Nov-16	5 216 260	301 240	Approved
Upgrade Road, Gravel	DR01461	6.42	8.98	CWDM/2016/IMMS 8006 - Upgrade on DR1461 (6.42 - 8.98)km Twee Jonge Gesellen	01-Nov-16	03-May-17	18 045 440	135 108	Approved
Upgrade Road, Gravel	DR01487	0	15.56	C0783.01: Upgrade/Regravel DR1487, Upgrade of DR2182 and MR539 - Algeria Road Phase II	27-Aug-19	08-Mar-21	109 682 440	129 103	On Hold
Upgrade Road, Gravel	DR01487	24	33.25	C0783.01: Upgrade/Regravel DR1487, Upgrade of DR2182 and MR539 - Algeria Road Phase II	27-Aug-19	08-Mar-21	65 203 250	91 072	On Hold
Upgrade Road, Gravel	DR01578	15.5	23	EDM/2016/IMMS 4865 - Upgrading on DR1578 (15.50 - 23.00)km	01-Apr-16	14-Mar-19	52 867 500	440 138	Under construction
Upgrade Road, Gravel	DR01578	15.8	23.3	C0822.03: Upgrade of DR1578 at km 15.8 to km 23.3 & km 31.13 to 34.2 - Friemersheim	26-Feb-19	03-Aug-20	52 867 500	605 822	Design
Upgrade Road, Gravel	DR01578	31.13	34.22	C0822.03: Upgrade of DR1578 at km 15.8 to km 23.3 & km 31.13 to 34.2 - Friemersheim	26-Feb-19	03-Aug-20	21 781 410	605 822	Design
Upgrade Road, Gravel	DR01609	0	6.43	C0851: Upgrade DR1609 - Rondevlei	08-Aug-17	04-May-18	45 325 070	637 275	Design
Upgrade Road, Gravel	DR01625	6.4	6.8	C0851: Upgrade DR1609 - Rondevlei	08-Aug-17	04-May-18	2 819 600	280 223	Design
Upgrade Road, Gravel	DR01661	39.86	43.58	C0847.01: Upgrade DR1661 km 39.86 - km 43,58 near Calitzdorp	09-Jul-19	15-Jul-20	26 222 280	165 131	On Hold
Upgrade Road, Gravel	DR01662	36.47	37.13	C1007.06: Upgrade Gravel Road DR01662 km 36.47 to km 37.13 - Dysselsdorp	07-Oct-16	13-Apr-17	4 652 340	142 917	Design
Upgrade Road, Gravel	DR01694	5.51	6.41	C1007.05: Upgrade Gravel Road DR01694 from km 0 to km 5.51 - Dysselsdorp	07-Oct-16	13-Apr-17	6 344 100	336 381	Design
Upgrade Road, Gravel	DR01699	0	1.2	C1008.01: Rehab of DR01688 from Calitzdorp to Spa & Upgrade DR01699	27-Nov-18	04-Mar-20	8 458 800	154 123	Design
Upgrade Road, Gravel	DR02160	0	12.46	C1010: Upgrade DR02160 between Vredenburg & Stompneus Bay	07-Jan-19	13-Jan-20	87 830 540	135 108	Design
Upgrade Road, Gravel	DR02160	12.46	18.21	C1010: Upgrade DR02160 between Vredenburg & Stompneus Bay	07-Jan-19	13-Jan-20	40 531 750	224 178	Design
Upgrade Road, Gravel	DR02197	2	4	C0832: Regravel Roads - Van Rhynsdorp Area	31-Oct-16	07-Nov-17	14 098 000	985 161	Design
Upgrade Road, Gravel	DR02203	15	22	C0832: Regravel Roads - Van Rhynsdorp Area	31-Oct-16	07-Nov-17	49 343 000	224 178	Design
Upgrade Road, Gravel	DR02210	0	5.44	C0834.02: Upgrade DR2210 km 0-5.44 & DR2213 km 0.48-5.06 - Vredendal Area	20-Jan-20	22-Sep-20	38 346 560	290 231	Design
Upgrade Road, Gravel	DR02212	7.48	8.48	C0832: Regravel Roads - Van Rhynsdorp Area	31-Oct-16	07-Nov-17	7 049 000	304 242	Design
Upgrade Road, Gravel	DR02213	0.48	5.06	C0834.02: Upgrade DR2210 km 0-5.44 & DR2213 km 0.48-5.06 - Vredendal Area	20-Jan-20	22-Sep-20	32 284 420	345 171	Design
Upgrade Road, Gravel	DR02217	1.18	17.36	C0832: Regravel Roads - Van Rhynsdorp Area	31-Oct-16	07-Nov-17	114 052 820	280 223	Design
Upgrade Road, Gravel	MR00276	0	6.72	C0852: Upgrade MR276 - Boontjieskraal	19-Jan-19	20-Jan-20	47 369 280	372 296	Design