A SOUTH AFRICAN PERSPECTIVE ON BRIDGE MANAGEMENT AND SOME UNIQUE PROBLEMS ENCOUNTERED

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ABSTRACT

This paper deals with the implementation of a new Bridge Management System (BMS) system adopted by the SA National Roads Agency Limited. Reasons are given as to why the present BMS was adopted and how it differs from other systems. A brief outline of the main aspects of the BMS is given. Also discussed is the overall road network Bridge Performance Indicators(s) adopted by the SA National Roads Agency Limited (the Agency). Examples on how the Overall Priority Index (OPI) and other information was used to identify and group bridge repair projects are given. The different approaches used for the procurement of contracting services to undertake the repairs and the problems encountered with the bridge repair design process are also dealt with. Finally some unique bridge problems encountered in South Africa are outlined.

KEY WORDS

BMS / PRIORITY / PERFORMANCE / CONDITION / INDEX / BCE

1. WHAT THE SA NATIONAL ROADS AGENCY LIMITED (THE AGENCY) WAS LOOKING FOR IN A BMS

The Agency, like most authorities, need's to allocate scare funds according to a system that not only allocates funds to projects where most needed, but also to where the long term benefit will be the most advantageous.

The four regional offices of the Agency each are allocated funds for repair of both roads and bridges. It is the aim to have good pavement and bridge management systems in place and so be placed in a position where one is able to identify projects in order of importance and also to keep long-term road expenditure at an optimum level. The management systems also ensure that funds are distributed according to need and thus some regions will not have the same budget allocation as others. It is important that the Pavement Management and Bridge Management Systems deliver credible information so that there is confidence in the prioritisation and planning process. This is essential in order to prevent regress to add-hoc decision making processes.

The timing of road rehabilitation and bridge rehabilitation projects are often out of phase. This is mainly due to roads needing rehabilitation or preventative maintenance on a more frequent basis than bridges. It is imperative for those who are responsible for keeping the bridge stock in a satisfactory condition that the funds for bridge projects do not get reallocated to road projects of perceived greater importance. For this not to happen it is imperative that a reliable and effective BMS is used, and that there is integration with other planning systems.

Prior to 1997 the Agency operated a condition based bridge management system for its approximately 2050 bridges. Those who used it regarded this BMS cumbersome and it never produced results that management had confidence in.

In 1996 the Agency evaluated several BMS's both locally and internationally. This included the then current system in updated form. After examining the different BMS's available it was decided to implement a BMS that focussed on actual defects rather than trying to determine the overall condition of all bridge elements. The new system had to be able to prioritise bridges in need of repair and had to have a budgeting module that could estimate the cost of repairs of bridges. It was also important that the system should use a simple, practical and appropriate visual inspection procedure. Ideally the ststem should make use of a single bridge inspection form.

2. THE BMS USED BY THE AGENCY

2.1. The STRUMAN BMS

Early in 1997 the Agency decided to adopt the STRUMAN Bridge Management System developed by the Council for Industrial and Scientific Research (CSIR) with assistance from Stewart Scott International (SSI). The system satisfied in broad terms the following:

- The system is defects based
- A simple & practical visual inspection procedure is followed
- A single bridge inspection sheet is used and is adequate for most bridges.
- Bridges in need of repair are prioritised (Condition Module).
- Cost Estimates for repairs can be done (Budget Module)

2.2. The basic philosophy behind the STRUMAN BMS

A detailed explanation of the STRUMAN BMS is given in a paper entitled " A Bridge Management System for the South African National Roads Agency by Nordengen, Welthagen & de Fleuriot" [1]. Only a brief outline will be given hereunder.

The main aspect of the system that distinguishes it from most other systems on the market is that it is defects based rather than condition based. The system is intended for use at network level planning.

The system requires that 21 basic bridge elements be evaluated. These are:

1. Approach Embankments
2. Guardrails on approaches
3. Waterway
4. Embankment protection
5. Abutment foundations
6. Abutments
7. Wing/retaining walls
8. Surfacing/ballast
9. Deck drainage
10. Kerbs/sidewalks
11. Barriers/parapets and handrails
12. Pier protection works
13. Pier foundations
14. Piers, pylons & columns
15. Bearings
16. Support drainage
17. Expansion Joints
18. Longitudinal members (decks & arches)
19. Transverse members (decks & arches)
20. Deck slabs & arches
21. Miscellaneous

2.3. The DER rating system

Being a defect-based system, each defect of a bridge element is rated according to its Degree (D), extent (E) and relevancy (R) to the bridge element in question. This is broadly known as the DER rating system. These three different aspects of only the worst defect affecting a bridge element are considered. Each is rated on a scale of 1 to 4. If the degree is shown as “0” then there is no defect present. Briefly the rating is as follows:

D = Degree or Severity of defect (ranging from 1=Minor to 4=Severe with 0=No defect)
E = Extent of the defect (ranging from 1=Local to 4=General)
R = Relevancy of defect to bridge element (ranging from 1=Min to 4=Critical)

2.4. Inventory Details

The system also makes provision for capturing basic inventory information of most of the major bridge elements. No further detail of this process is dealt with in this paper.

2.5. BMS Bridge Inspections

An important criteria in the selection of a BMS for the Agency, was the simplicity and practicality of bridge inspections. The greatest advantage of the adopted BMS system inspection methodology is that the bridge inspector is not required to condition rate each bridge element but only rates defects observed. The total time on site is thus reduced to the absolute minimum.

Due to the importance of understanding how the relevancy (R) rating of a defect affects the BMS result, the bridge inspectors have to be professionally qualified with a minimum of 5 years bridge design experience. A lot of emphasis is placed on the quality of the inspection data to ensure the quality of the output of the BMS. All bridge inspectors are given a two to three day training course prior to bridge inspections taking place.

Principal Inspections are generally undertaken every 5 years and at the end of each bridge repair project.

2.6. A typical completed inspection sheet

Table 1 below is an example of how a typical completed inspection sheet looks. The following is noteworthy:

- The inspection focuses on the Degree (D), Extent (E) and Relevancy (R) of defects.
- The Relevancy (R) rating of a defect considers the effect of the defect on the future performance of the associated bridge element and its effect on the bridge as a whole fulfilling its function. It is a parameter that requires engineering judgement.
- Bridge elements without defects require no input by the inspector (D=0).
- Estimates are made of the quantities of repair items and in what time frame they should be undertaken.
- A photographic record of defects forms part of the inspections. These are stored electronically.
- Provision is made for stating the urgency of specific repairs as well as for monitoring defects. Any condition that endangers the immediate public safety is recorded as “make safe” (MS).

Table 1: A Typical completed inspection sheet

SA National Roads Agency Ltd BRIDGE MANAGEMENT SYSTEM	BRIDGE Field Inspection Sheet	No. Name	N001_01N_B6691 Agter Paarl Road over Road Bridge

Inspection Type:		Inspector	Firm	Date			
Current	PR	M Smuts	VKE CTN	99/05/07	Route/Section	N001	01N
Last Principal	PR	M Smuts	VKE CTN	99/05/07	Route km	47,29	
Last Monitoring	MO				Other Bridge No	4453	
Last Maintenance	MA				N Route Over/Under	Under	
Last Verification	VE				Feature Name	Agter Paarl Road	
					Feature Rd No		

Bridge Type	Simply supported	No of spans	4	Min Vertical	Pos/Span	NBC /	NBC /	SBC / I	SBC / F
Year constructed	70/01/01	Overall length	112,4	Clearance	Min height	8,395	7,5	6,33	5,21
Bridge orientation	North/South	Angle of skew	58	Direction of river flow					

Time (Hours) Inventory	0	Inspection	0	Reporting	0	Capturing	0

INSPECTION ITEM			D	E	R
1. Approach Embankment	N	A	2	1	1
	S	A	0		
2. Guardrail			2	1	1
3. Waterway			X		
4. Appr.Emb. Prot.Works	N	A	0		
	S	A	0		
5. Abutment Foundations	N	A	U		
	S	A	U		
6. Abutments	N	A	3	3	3
	S	A	3	3	3
7. Wing/Retaining walls	N	A	3	2	2
	S	A	3	2	2
8. Surfacing			0		
9. Superstructure Drainage			X		
10. Kerbs/ Sidewalks			0		
11. Parapet			3	3	2
21. Miscellaneous Items			X		

SUPPORTS

	12 Pier Protection Works			13 Pier Foundation			14 Piers & Columns			15 Bearings			16 Support Drainage			17 Expansion Joints		
	D	E	R	D	E	R	D	E	R	D	E	R	D	E	R	D	E	R
AS	-	-	-	-	-	-	-	-	-	3	4	2	U			4	4	3
AN	-	-	-	-	-	-	-	-	-	3	4	2	U			4	4	3
P1	0			U			3	2	2	2	1	1	U			4	4	3
P2	0			U			3	2	2	2	1	1	U			4	4	3
P3	0			U			3	2	2	2	1	1	U			4	4	3

SPANS

	18 Longitudinal Members			19 Transverse Members			20 Decks and Slabs		
	D	E	R	D	E	R	D	E	R
S1	4	3	3	X			3	2	2
S2	4	3	3	X			3	2	2
S3	4	3	3	X			3	2	2
S4	4	3	3	X			3	2	2

tem	Position	Activity	Qty	Unit	U	MS	Remarks	Monitor Freq	Photos
1.	NA	4. Inlets/outlets - clean	1	no	1	No	Inlet blocked	0	01
1.	NA	10. Side drains - clean	10	m	1	No	Vegatation on verge	0	02
2.	P1,P3	2. Replace rails	15	m	1	No	Collision damage	0	03,04
6.	BA	9. Apply protective coating	26	m2	2	No	Pattern cracking due to AAR	0	05-08
6.	BA	13. Clean concrete surface	26	m2	2	No	Severe staining	0	05-08
7.	AL	3. Seal, repair cracks > 0.3 mm	4	m	2	No	Horizontal cracks	0	10
7.	AL	7. Apply protective coating	6	m2	1	No	Pattern cracking due to AAR	0	09-11
7.	AL	13. Clean concrete surface	6	m2	1	No	Staining	0	09-11
11.	AL	12. Reconstruct parapet (Not NJ)	270	m3	2	No	Pattern cracking due to AAR	0	12,13
11.	W	20. Replace steel/aluminium handrail	6	m	1	No	Collision Damage	0	14
14.	AP	4. Apply protective coating	280	m2	2	No	Pattern cracking due to AAR	0	15-19
14.	AP	7. Clean concrete surface	280	m2	2	No	Concrete stained	0	15-19
14.	P1	1. Repair spalled concrete	0,5	m3	1	No	Western column	0	15
14.	P2	2. Seal, repair cracks > 0,3 mm	6	m	2	No	Verticle cracks	0	17,18
15.	AL	8. Clear obstructions to movement	70	no	1	No	Clean gap around bearings	0	20-22
17.	AL	2. ? Replace concrete nosing	90	m	2	No	All expansion joints are leaking - to be replaced	0	23-27
18.	AS	2. Seal, repair cracks > 0,3 mm	380	m	4	No	Major longitudinal cracks in soffit - 10mm max	0	28-38
18.	AS	4. Apply protective coating	850	m2	2	No	Pattern cracking due to AAR	0	32-39
18.	AS	6. Clean concrete surface	850	m2	2	No	Concrete stained	0	28-39
19.	BA	2. Seal, repair cracks > 0,3 mm	8	m	4	No	Horizontal cracks	0	40,41
19.	BA	4. Apply protective coating	25	m2	2	No	Pattern cracking due to AAR	0	40,41
19.	BA	5. Clean concrete surface	25	m2	2	No	Concrete stained	0	40,41
20.	AS	2. Seal, repair cracks > 0,3 mm	5	m	2	No	Cracks	0	43-45
20.	AS	4. Apply protective coating	250	m2	2	No	Pattern cracking due to AAR	0	42-45
20.	AS	7. Clean concrete surface	250	m2	2	No	Concrete stained	0	42-45
20.	S2	1. Repair spalled concrete	0,5	m3	1	No	None	0	42

Inspector's assessment of structure condition and further comments:

Major longitudinal cracks in deck soffit - up to 10mm wide - needs urgent attention.
All exposed concrete surfaces are stained and covered with pattern cracking due to AAR.
All exposed concrete surfaces to be painted with a protective coating.

Further inspection needed ? Y/N	No	IF FURTHER INSPECTION REQUIRED IS Y:
Was UBIU used ? Y/N	No	Then please indicate any special requirements ie. 6m Ladder, Bush
Is the UBIU needed for future insp's? Y/N	No	cutting, UBIU, better weather etc. If nothing please state "none"

D - DEGREE							E - EXTENT				R - RELEVANCY				U - URGENCY					
NA	UA Insp	None	Minor	Fair	Poor	Severe	Local	>Local	<Gnl	General	Min	Moderate	Major	Critical	Record	Monitor	Routine	< 5 yrs	< 2 yrs	ASAP
X	U	0	1	2	3	4	1	2	3	4	1	2	3	4	R	0	1	2	3	4

3. THE INTEGRATED MANAGEMENT SYSTEMS APPROACH

The BMS forms part of the overall Integrated Transportation Information System (ITIS) adopted by the Agency. The ITIS system is a comprehensive management information tool used to address various facets of strategic and tactical planning, design, construction and maintenance of the entire road network. The considerable investment in this system has resulted in the following benefits to the Agency as a whole:

- It allows seamless integration of GIS within management systems;
- It enhances productivity by enhanced applications & processes with a central database;
- It has a common user interface ensuring that existing windows users will be able to access and use the system fairly easily;
- It is fully user customisable including any BMS requirements;
- Through the Internet information can be made available to all users at any location.

4. BRIDGE PERFORMANCE INDICATORS

4.1. The Agency's Road Network Indicators

The Agency's contribution towards increasing South Africa's global competitiveness is to ensure that the primary national road network functions efficiently. In order to achieve this, the Agency is implementing a comprehensive performance management framework within which the Agency's performance can be benchmarked. The use of performance indicators relating to the road network fulfils this need. The following performance indicators have been identified for the primary road network as stated in the South African National Roads Agency Limited publication Horizon Twenty Ten [(2)]:

- Smooth Travel Exposure (STE)
- Low Rut Exposure (LRE)
- High Texture Exposure (HTE)
- Bridge Condition Exposure (BCE)

All the above indicators form part of the Integrated Transportation Information System (ITIS) of the Agency, which is accessible by employees of the Agency via the intranet. Presently the system is being updated to give access to consultants via the Internet which specific password protection. The module dealing with bridges and culverts is called ITIS Bridge.

Only the Bridge Condition Exposure (BCE) index is described in this paper.

4.2. Description of the Bridge Condition Exposure (BCE) Index

Description of BCE: The proportion of vehicles per year that travel over or under bridges with a Condition Index (CI) higher than a specified level.

Purpose: To monitor whether bridges are providing acceptable travel conditions.

Considerations: The Bridge Condition Exposure (BCE) indicator represents the proportion of vehicles that travel over or under bridges with a Condition Index (CI) higher than a specified level.

The Agency presently has set the BCE target as 90% for travel over or under bridges with a CI higher than 80 (The CI=100 for a bridge with no defects at all).

Presently there is further work being done on the algorithm for the Condition Index (CI) that may change the targets set for the Agency in the future.

Additional indices that are used are: An Average Bridge Condition Index (ABCI), which is the average condition of the bridges ignoring the relative importance of individual bridges; and a Weighted Bridge Condition Index (WBCI), which is a traffic-weighted bridge condition index. Neither of these two additional indices form part of the Agency's annual reports.

4.3. Example of how the different Bridge Indices are calculated

The Condition Index (CI) is obtained from the BMS in use. It must be noted that the bridge indices can be worked out providing each bridge is allocated CI by the applicable BMS used and that the traffic volumes (AADT) crossing over or under the specific bridge are known.

The Average Bridge Condition Index (ABCI) is calculated as follows:

ABCI = Sum [CI] / No of Bridges (n)

$$= \sum [\text{ CI }] / n$$

The Weighted Bridge Condition Index (WBCI) is calculated as follows:

WBCI = Sum [CI * AADT] / Sum [AADT]

$$= \sum [\text{ CI * AADT }] \;/\; \sum [\text{ AADT }]$$

The Bridge Condition Exposure (BCE) is calculated as follows:

BCE = Sum [AADT where CI of bridge >specified level] / Sum [AADT]

$$= \sum [\text{ AADT (bridge specific) }] \;/\; \sum [\text{ AADT (all bridges) }]$$

Table 2 gives some fictitious CI values of ten bridges and shows the method of calculation of each index.

Table 2: Example of CI and AADT of ten bridges

ITEM	CI	AADT	AADT * CI	AADT where CI>80
Bridge 1	60	1 100	66 000	
Bridge 2	75	1 550	116 250	
Bridge 3	81	2 980	241 380	2 980
Bridge 4	100	2 620	262 000	2 620
Bridge 5	90	2 030	182 700	2 030
Bridge 6	58	750	43 500	
Bridge 7	85	950	80 750	950
Bridge 8	90	310	27 900	310
Bridge 9	60	240	14 400	
Bridge 10	65	520	33 800	
Sum ($\sum$)	764	13 050	1 068 680	8 890
Average Bridge CI ABCI = 764/10 = 76,4		WBCI = 1068680/13050 = 81,9		BCE = 8890*100/13050 = 68,1%

Thus in the above example the BCE target of 90% for travel over bridges with a CI higher than 80 has not been achieved.

5. THE RESULTS OBTAINED FROM THE BMS SYSTEM

The BMS used by the Agency is still in its infancy and thus several years of compatible historical data is not available. One round of principle inspections took place in 1998/2000 and this presently forms the sole historical data record. As previously mentioned the Agency's previous BMS was a condition-based system, which means that its inspection data is not compatible with the new BMS in use.

By being able to adjust certain built in system and weighting factors in the current BMS program one is able to fine-tune the output to give results that make sense. This is critical if confidence in the system is to be built up. In the Condition Module bridges are prioritised in order of the need for repair/rehabilitation. All bridge elements have adjustable weighting factors built into the algorithms so that important elements such as abutments, piers and decks that have defects with a high degree (D) rating combined with a high relevancy (R) rating have a greater influence on the Priority Index (PI) of a bridge than more minor items.

Table 3 is an extract taken from the output generated by the BMS Condition Module. The user of the BMS is able to select the method of ranking and in the example the bridges are ranked according to the Priority Index (PI). It can be readily seen that certain bridges high on the priority list occur in groups (shown shaded). This is logical as bridges in the same vicinity would be subject the similar environmental degradation and were constructed in the same time period with similar materials. In the example there are several bridges on Route N2 section 11 that are high on the priority list.

The most important aspect that needed verification was to determine that the bridges at the top of the list were in fact those that were in need of urgent repair. Verification inspections to check on the worst bridges were done in order to check on the reliability of the bridge inspection data. It was found that bridge inspectors tended to be rather conservative, especially if the bridges inspected along a route were in a good condition.

Table 3: Priority List as generated by BMS Condition Module (OPI ranked)

SA National Roads Agency Ltd.

BRIDGE MANAGEMENT SYSTEM

Condition - Prioritisation Report

Date: 20-May-03

Bridge number	Bridge name	Province	Route nc	Section	km	Last Inspection	CI	CI Rank	PI	PI Rank	FI	FI Rank	OPI	OPI Rank
N004_07EX_B1499	River Side Service Bridge 1 over N4/7X	Mpumalanga	N004	07EX	35.4	1	62	1	36	1	98	1919	36	1
N007_08N_B102.IB48	Orange River Bridge (Vioolsdrif Bridge)	Northern Cape	N007	08N	117	17	80	12	42	2	63	748	42	2
N003_01N_B97	Maryvale Road Grade Seperation	KwaZulu-Natal	N003	01N	15.3	26	82	22	47	3	65	1719	47	3
N002_02E_B643	PALMIET RIVER BRIDGE	Western Cape	N002	02E	23.1	16	76	4	50	4	63	1087	50	4
N002_01E_B60	BRIDGE OVER TRIBUTARY TO EERSTE RIVEF	Western Cape	N002	01E	33.7	12	76	5	50	5	63	1085	50	5
N001_01N_B6691	Agter Paarl Road over Road Bridge	Western Cape	N001	01N	47.29	7	76	6	51	6	65	1749	51	6
N003_12N_B433	GILLOOLYS I/C	Gauteng	N003	12N	28.6	15	87	79	56	7	53	317	56	7
N002_24N_B1169	Little Amanzimtoti River Freeway Bridge	KwaZulu-Natal	N002	24N	15.95	28	88	111	56	8	63	670	56	8
N003_12N_B432	NICOL ROAD BRIDGE	Gauteng	N003	12N	27.797	17	83	27	57	9	55	335	57	9
N003_12N_B628	Grey Ave I/C Bridge	Gauteng	N003	12N	16.2	26	93	450	58	10	63	1354	58	10
N001_03N_B1887	KEURBOSCH ROAD OVER RAIL	Western Cape	N001	03N	34.15	4	77	7	59	11	63	823	59	11
N001_17N_B1057	KROONSTAD RAIL BRIDGE	Free State	N001	17N	73.53	25	79	10	59	12	63	756	59	12
N002_11E_B768A	LINTON (A) I/C	Eastern Cape	N002	11E	23.26	25	94	582	60	13	55	379	60	13
N002_11W_B768B	LINTON (B) I/C	Eastern Cape	N002	11W	23.26	25	94	583	60	14	55	388	60	14
N002_11E_B1292	BURMAN RAIL G/S II	Eastern Cape	N002	11E	34.6	4	71	2	60	15	55	432	60	15
N002_01E_B726	FIRGROVE INTERCHANGE BRIDGE	Western Cape	N002	01E	34.2	21	87	82	60	16	63	1183	60	16
N002_11E_B1213-Y	COEGA RIVER BRIDGE	Eastern Cape	N002	11E	51.8	13	90	177	61	17	63	695	61	17
N002_11W_B1290B	BURMAN RAIL (B) G/S I	Eastern Cape	N002	11W	34.5	5	75	3	62	18	55	431	62	18
N002_11E_B1293	BURMAN RAIL G/S III	Eastern Cape	N002	11E	34.4	5	81	18	63	19	55	433	63	19
N017_02E_B1434	Guthrie Road Bridge	Gauteng	N017	02E	8.7	15	88	89	63	20	65	1448	63	20
N001_14S_B1062	KINDERSPRUIT	Free State	N001	14S	89.52	9	79	9	63	21	63	757	63	21
N002_01E_B757	MACASSAR BEACH UNDERPASS	Western Cape	N002	01E	30.79	21	85	44	63	22	98	1892	63	22
N002_01E_B50	KUILS RIVER BRIDGE	Western Cape	N002	01E	23.4	12	81	19	63	23	63	1083	63	23
N002_24N_B854	Winkelspruit Interchange Grade Separation	KwaZulu-Natal	N002	24N	13.5	18	93	384	63	24	63	1065	63	24
N017_02E_B1542	Tonk Meter Road Bridge	Gauteng	N017	02E	32.5	17	82	20	64	25	65	1459	64	25
N004_03E_B391	Swartbos Road I/C Bridge	Mpumalanga	N004	03E	29.6	10	83	25	64	26	65	1460	64	26
N001_21N_B128A	Zambezi drive interchange bridge 128A	Gauteng	N001	21N	40.95	3	84	29	65	27	63	994	65	27
N011_05N_B1213-Z	Rail over Road Bridge	Mpumalanga	N011	05N	1.3	15	80	14	65	28	65	1531	65	28
N001_17S_B890B	STEYNSRUS INTERCHANGE	Free State	N001	17S	68.6	19	86	51	65	29	65	1684	65	29
N011_09N_B1795	Arendsfontein River	Mpumalanga	N011	09N	35.8	24	82	21	65	30	63	1176	65	30
N006_04N_LS019	HOLSPRUIT NO 3	Eastern Cape	N006	04N	91.4	20	88	99	66	31	63	1082	66	31
N002_01E_B758	Helderberg Road over Rail Bridge	Western Cape	N002	01E	35.6	14	88	112	66	32	63	1086	66	32
N006_04N_LS018	HOLSPRUIT NO 2	Eastern Cape	N006	04N	89	20	88	96	67	33	63	1111	67	33
N017_02E_B1433	Orsbon Road Bridge	Gauteng	N017	02E	7.6	15	86	63	67	34	65	1436	67	34
N004_06EX_B1559	Elands river	Mpumalanga	N004	06EX	10.5	5	89	137	67	35	63	883	67	35
N002_11W_B1289B	NEW BRIGHTON RAIL BRIDGE. B.	Eastern Cape	N002	11W	33.55	3	93	451	67	36	55	429	67	36
N002_11E_B1289A	NEW BRIGHTON RAIL BRIDGE. A.	Eastern Cape	N002	11E	33.549	3	93	437	67	37	55	436	67	37
N002_02E_B589	SIR LOWRYS PASS VIADUCT	Western Cape	N002	02E	13.11	21	90	191	68	38	63	1175	68	38
N002_01E_B725	FAURE INTERCHANGE BRIDGE	Western Cape	N002	01E	28.25	23	80	15	68	39	98	1888	68	39
N001_21S_B128B	Zambezi drive interchange Bridge	Gauteng	N001	21S	40.95	3	83	28	68	40	63	995	68	40
N002_12EX_B1757	ALEXANDRIA G/S	Eastern Cape	N002	12EX	10.05	6	85	45	68	41	53	184	68	41
N002_11E_B1294	BURMAN RAIL BRIDGE No. 4	Eastern Cape	N002	11E	34.43	18	89	136	68	42	55	449	68	42
N001_20N_B181	DODGE STREET	Gauteng	N001	20N	47.2	11	91	246	68	43	55	366	68	43
N001_21N_B109C	IRENE ROAD/RAIL B109C	Gauteng	N001	21N	19.1	7	94	595	68	44	63	1001	68	44
N007_08N_LS002	Unknown LS002	Northern Cape	N007	08N	1.8	19	89	150	68	45	73	1867	68	45
N001_20N_B179	KYALAMI ROAD	Gauteng	N001	20N	49.2	16	86	71	69	46	53	179	69	46
N003_12N_B488	EUGENIA ROAD PEDESTRIAN BRIDGE	Gauteng	N003	12N	47.6	5	92	282	69	47	55	327	69	47
N003_12N_B26A	Natalspruit RD/RL Bridge	Gauteng	N003	12N	13.1	20	94	521	69	48	98	2000	69	48
N001_20N_B183	Cambridge Road	Gauteng	N001	20N	44.9	4	91	266	69	49	53	172	69	49
N001_20N_B261A	C.R SWART DRIVE	Gauteng	N001	20N	35.1	14	92	298	69	50	53	219	69	50
N003_12S_B631B	Alberton Bridge	Gauteng	N003	12S	19.6	30	80	16	69	51	98	2002	69	51
N006_04N_B1471	BROWNS STREAM	Eastern Cape	N006	04N	35.38	19	89	131	69	52	98	1983	69	52
N004_05EX_B1554	Driefonteinspruit	Mpumalanga	N004	05EX	43.4	17	91	238	69	53	63	912	69	53

Immediately obvious from Table 1 above is that those bridges in need of urgent repair fall into groups. Examples of such groups are shown shaded. The two groups of shaded bridges shown are firstly on the Agency's National Route N2 Section11 and secondly on National Route N6 Section 4.

6. HOW THE BMS PRIORITY LISTS WERE USED TO IDENTIFY REPAIR PROJECTS

Having established where the bridges highest on the priority list are situated, the next step is to generate a list of bridges that is region specific. The bridges are then listed in order of position rather than priority. Such al list is shown in Table 4 below.

Table 4: List of bridges on a specific route and Section (N2 Section 11)

Analysis Year:	2001/02										
Bridge Number	Bridge Name	Province	Route No	Section	km	OPI Rank	Seen ?	Prio Pos	Project	Cost estimated BMS *3	General Comment
N006.03.B2035	HOBBS HILL	Eastern Cape	N006	03	4.10	871			SR	597 240	Repaired in SSI contract
N002.11.B761	RIETFONTEIN G/S	Eastern Cape	N002	11	0.91	1 321			SR 1	246 600	Handrails (127m) & Joints 47m
N002.11.B762	UPINGTON G/S	Eastern Cape	N002	11	4.35	322		P400	SR 1	245 160	Handrails (127m) & Joints 52m
N002.11.B763	DRAAIFONTEIN G/S	Eastern Cape	N002	11	7.19	334		P400	SR 1	235 440	Handrails (130m)
N002.11.B1	KABEGA PEDESTRIAN BRIDGE	Eastern Cape	N002	11	21.49	998			SR 1	77 400	Seal halving joints to stop det
N002.11.B1277A	KABEGA (A) ROAD BRIDGE	Eastern Cape	N002	11	22.80	1 356			SR 1	39 600	Repair grouting & Provide column prot
N002.11.B1277B	KABEGA (B) ROAD BRIDGE	Eastern Cape	N002	11	22.80	1 357			SR 1	39 600	Repair grouting & Provide column prot
N002.11.B768A	LINTON (A) I/C	Eastern Cape	N002	11	23.26	13		P400	SR 1	427 500	Major repairs to NJ & Decks
N002.11.B768B	LINTON (B) I/C	Eastern Cape	N002	11	23.26	14		P400	SR 1	423 000	Major repairs to NJ & Decks
N002.11.B769	FRAMESBY PEDESTRIAN BRIDGE	Eastern Cape	N002	11	24.41	190		P400	SR 1	39 840	Seal halving joints to stop det
N002.11.B1278	KRAGGA KAMMA I G/S	Eastern Cape	N002	11	24.77	721			SR 1	64 200	Re-set bearings & diaphragm of joints
N002.11.B1279	KRAGGA KAMMA II I/C	Eastern Cape	N002	11	25.35	591			SR 1	174 480	Re-set bearings & diaphragm of joints
N002.11.B554	STANDFORD ROAD BRIDGE	Eastern Cape	N002	11	25.59	525			SR 1	117 990	Handrails, guardrails etc
N002.11.B1280	KRAGGA KAMMA ROAD BRIDGE No. 3	Eastern Cape	N002	11	25.70	704			SR 1	105 315	bearings & guardrails,minor repairs
N002.11.B1281	COTSWOLD PEDESTRIAN BRIDGE	Eastern Cape	N002	11	26.45	897			SR 1	17 160	Check possible crack sealing & check ASR
N002.11.B770	COTSWOLD INTERCHANGE BRIDGE	Eastern Cape	N002	11	27.08	599			SR 1	57 525	Check & possibly seal cracks & repair spalled concrete
N002.11.B1282B	WOOLHOPE ROAD BRIDGE. B.	Eastern Cape	N002	11	28.80	878			SR 1	156 126	Handrails, check bearings
N002.11.B1282A	WOOLHOPE ROAD BRIDGE.A.	Eastern Cape	N002	11	28.80	969			SR 1	104 970	Handrails, check bearings
N002.11.B1283A	KEETON STREET BRIDGE. A.	Eastern Cape	N002	11	30.91	259		P400	SR 1	20 400	New handrail & check and seal cracks in deck if required, check bearings
N002.11.B1283B	KEETON STREET BRIDGE. B.	Eastern Cape	N002	11	30.91	419			SR 1	111 180	New handrail & check and seal cracks in deck if required, check bearings
N002.11.B772A	COMMERCIAL ROAD INTERCHANGE. A.	Eastern Cape	N002	11	31.40	1 175			SR 1	349 800	Handrails & minor other repairs
N002.11.B772B	COMMERCIAL ROAD INTERCHANGE. B.	Eastern Cape	N002	11	31.50	719			SR 1	370 440	Handrails & minor other repairs
N002.11.B1284	CADLE STREET BRIDGE	Eastern Cape	N002	11	31.86	1 494			SR 1	128 970	Handrails & minor other
N002.11.B1287	PAPENKUILS RIVER BRIDGE No.2	Eastern Cape	N002	11	33.18	1 575			SR 1	271 530	Handrails & minor other
N002.11.B1286	PAPENKUILS RIVER BRIDGE No.1	Eastern Cape	N002	11	33.20	224		P400	SR 1	307 239	Handrails & check cracks/ design
N002.11.B773B	KEMPSTON ROAD INTERCHANGE. B.	Eastern Cape	N002	11	33.30	545			SR 1	484 920	Handrails & bearings replace ?
N002.11.B773A	KEMPSTON ROAD INTERCHANGE. A.	Eastern Cape	N002	11	33.30	571			SR 1	492 480	Handrails & bearings replace ?
N002.11.B1288	PAPENKUILS RIVER BRIDGE No.3	Eastern Cape	N002	11	33.40	515			SR 1	260 100	Handrails & other minor
N002.11.B1289A	NEW BRIGHTON RAIL BRIDGE. A.	Eastern Cape	N002	11	33.55	37		P400	SR 1	1 190 400	Halving joint repairs etc
N002.11.B1289B	NEW BRIGHTON RAIL BRIDGE. B.	Eastern Cape	N002	11	33.55	36		P400	SR 1	1 192 260	Halving joint repairs etc
N002.11.B1293	BURMAN RAIL G/S III	Eastern Cape	N002	11	34.40	19	Y	P400	SR 1	918 360	Major repairs to NJ & Decks
N002.11.B774B	BURMAN ROAD INTERCHANGE BRIDGE	Eastern Cape	N002	11	34.40	383		P400	SR 1	444 960	Joints, handrails & check
N002.11.B774A	BURMAN ROAD INTERCHANGE BRIDGE	Eastern Cape	N002	11	34.40	694			SR 1	401 370	Joints, handrails & check
N002.11.B1291	BURMAN ROAD BRIDGE No. 2	Eastern Cape	N002	11	34.41	420			SR 1	148 320	Handrail & sealing of parapets?
N002.11.B1296	BURMAN RAIL BRIDGE No. 6	Eastern Cape	N002	11	34.41	1 152			SR 1	1 597 770	Expansion joints chiefly & handrails
N002.11.B1295	BURMAN RAIL BRIDGE No. 5	Eastern Cape	N002	11	34.42	100		P400	SR 1	2 308 845	Handrail & concrete etc spalling
N002.11.B1294	BURMAN RAIL BRIDGE No. 4	Eastern Cape	N002	11	34.43	42	Y	P400	SR 1	5 326 350	Major repairs incl canal pier
N002.11.B1290B	BURMAN RAIL (B) G/S I	Eastern Cape	N002	11	34.50	18	Y	P400	SR 1	987 000	Major repairs
N002.11.B1290A	BURMAN RAIL (A) G/S I	Eastern Cape	N002	11	34.55	312		P400	SR 1	848 490	Fairly major sub-structure
N002.11.B1292	BURMAN RAIL G/S II	Eastern Cape	N002	11	34.60	15	Y	P400	SR 1	1 181 250	Major repairs
N002.11.B776	DEAL PARTY PEDESTRIAN BRIDGE	Eastern Cape	N002	11	35.86	77		P400	SR 1	475 200	Demolish span over road or repair our portion
N002.11.B205A	SWARTKOPS RIVER BRIDGE. A.	Eastern Cape	N002	11	40.30	291		P400	SR 1	603 360	Decks need repair & design check
N002.11.B205B	SWARTKOPS RIVER BRIDGE. B.	Eastern Cape	N002	11	40.30	961			SR 1	992 490	Pier capping etc needs repair/ strengthening/ design check
N002.11.B48A	AMSTERDAMHOEK (A) I/C	Eastern Cape	N002	11	41.65	1 908			SR 1	81 900	Joint repair
N002.11.B582	St GEORGES STREET I/C	Eastern Cape	N002	11	45.08	1 564			SR 1	390 600	Joint repairs
N002.11.B1213-Y	COEGA RIVER BRIDGE	Eastern Cape	N002	11	51.80	17	Y	P400	SR 1	172 800	Stress top of piers or bind together
N002.11.B1215	SUNDAYS RIVER BRIDGE	Eastern Cape	N002	11	64.70	1 326			SR 1	841 800	Handrail to be replaced/ check bearing
									SR1	**25 472 490**	

The approach adopted by the Agency is to group bridge repair projects into logical projects that could be done by one or more contractors. These are then registered as stand-alone bridge repair projects. Such a project is shown in the table above.

Once a project is identified consulting engineers are appointed to do detail investigation,, design, documentation and to do the required drawings of repairs (all repairs must be indicated on drawings for future reference which includes any coatings).

Where single isolated bridges occur that need repair the Agency determines if there are any road rehabilitation or reconstruction projects to be done in the vicinity of such a bridge. If there were such a road project then the repair of the bridge would be included as part the work scope the roads project. This however generally only applies where bridge repairs are of not sufficient value to justify a separate bridge project. To date this dual approach of firstly grouping bridges into bridge repair projects and secondly to add the repair of a single bridge that is isolated into a road project has been successful.

7. PROBLEMS ENCOUNTERED DURING THE BUDGETING, DESIGN PROCESS AND THE CONSTRUCTION STAGES OF BRIDGE REPAIR PROJECTS

The first problem encountered was that the budgeted repair costs in the BMS budget module is estimates worked out from repair items based on the visual defects observed. These itemised repair items did not take into account such aspects as scaffolding, traffic accommodation or access problems. Thus a small, but relevant spall repair that is on the side of the soffit of a bridge deck situated over a busy road would result in expenditure far in excess of the BMS estimated cost of the required repair. To overcome this problem in the short term the budget figure in the BMS Budget module was roughly tripled in value to get realistic estimated project values. It must be stated however that this is not the fault of the BMS system but rather that the repair and associated cost items were not properly documented for the first bridge inspections that took place. This will be adjusted before the next inspector training sessions and bridge inspections take place. It is expected that the BMS budget module will give better results once the necessary adjustments are done.

A problem encountered by consultants was the dearth of information with regard to previous repairs to bridges as there was previously no policy in place as to how to document repairs done. This has proved to be especially problematical where bridges had been previously coated with water repellent silanes or barrier coatings, as the specification of the correct compatible products for new repairs is difficult. It is now mandatory that for all bridge repair projects undertaken, the consulting engineer must produce drawings on which all the repairs to be undertaken are described and the location clearly indicated. In addition the repair information must be accurately updated during construction on “Record” drawings. These “Record” or “As-built” drawings also must include a list all the actual repair products used.

During the design phase of bridge repair projects it was found that consultants tended to err on the side of caution that resulted in unrealistically high estimated project costs. It must be emphasised by the client to consultants involved in compiling specifications and drawings for the repair of bridges that not each and every defect in fact needs repair. A very pragmatic approach needs to be encouraged. Some defects can, without risk or unacceptable aesthetic consequences, be left without repair for the remaining life of the bridge.

Due to the fact that the bridge stock in South Africa has only recently started showing signs of deterioration, a major problem encountered by is that by en large bridge designers are relatively inexperienced when it comes to the repair and preventative maintenance of bridges. Most bridge engineers have spent most of their careers designing new structures. With South Africa moving towards a developed country status, as far as infrastructure is concerned, the shift towards bridge maintenance actions is gaining momentum. South African bridge engineers will have to develop their bridge rehabilitation skills further in order to remain relevant.

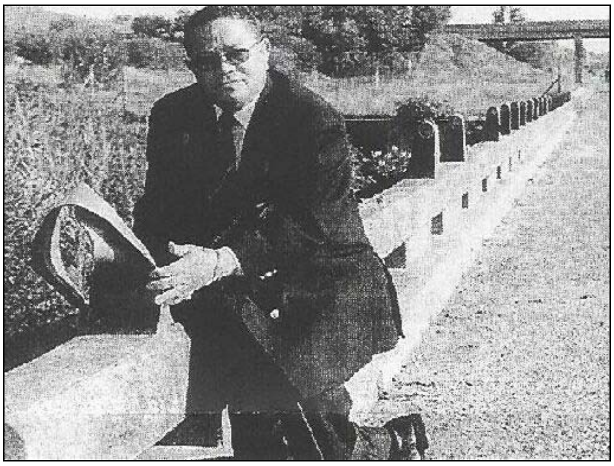
Another aspect that needs more attention is that there is a dearth of guidelines and specifications in South Africa relating to the repair of bridges and structures. As is common worldwide, suppliers of repair products generally claim "miracles" for their products. When such products fail then inevitably the excuse given is: "The Contractor applied our product incorrectly". To overcome this problem the Agency has now written into its standard contract documents that the Contractor and Supplier of products must give product performance guarantees. Generally the guarantees required for coatings are 12 years. All newly installed proprietary joints have to be guaranteed for a period of 15 years by the main Contractor and the manufacturer of the proprietary joint. Proprietary joints also have to have Agrément South Africa accreditation and joint manufacturers now have to indicate who the approved installers of their joints are as part of the accreditation process. With this approach it has been noticed that suppliers of products take a far greater interest during the application of their products on site.

8. SOME UNIQUE BRIDGE PROBLEMS ENCOUNTERED IN SOUTH AFRICA

The theft of aluminium or other metal components from road and bridges is an ongoing problem to the Agency. Unfortunately unscrupulous scrap metal dealers form a ready second-hand market for metallic components, particularly aluminium

The theft of full height aluminium railings off pedestrian bridges is particularly problematic due to the obvious danger to the pedestrians falling off such bridges. Aluminium road studs are also regularly stolen, as are cast iron bridge number plates. Photograph 1 below shows missing pedestrian railings off a bridge whereas Photograph 2 shows Mr Meyer the Western Cape provincial Minister of Transport at one of the road bridges owned by the Agency where the hand railings have been stolen.

Photograph 1: Stolen pedestrian railings



Photograph 2: Missing handrails

Photograph 3 shows the theft of an aluminium road joint that recently occurred. Dieseline was poured over the joint and set alight to melt the rubber so that the aluminium could be removed. It is tragic that the amount that the thief gets for the aluminium is negligible when compared to the cost of repairing the elements.

Photograph 3: Theft of aluminium road joint

It is presently policy at the Agency that all stolen bridge handrails be replaced with reinforced concrete rails as shown in Photograph 4. Photograph 5 shows a new concrete full height pedestrian railing. Pedestrian railings may be manufactured in concrete or polycrete (resin based products). The polycrete railings have been extensively used by the Agency with great success.

Photograph 4: New concrete handrails

Photograph 5: New pedestrian rails

Bridge number plates are now manufactured out of non-metallic materials with no scrap value.

Another unfortunate problem, which has occurred in isolated cases, is that criminals have dropped objects such as bricks or boulders onto vehicles passing below bridges. If an accident occurs the unfortunate motorist is then robbed. This problem has typically only occurred near informal settlements or townships. At some locations bridges have been caged to prevent such criminal activity. Photographs 5 & 6 show examples of cages on a road bridge and a pedestrian bridge.


Photograph 5: Cage on road bridge


Photograph 6: Caged pedestrian bridge

9. CONCLUSION

This paper presented the key aspects pertaining to the BMS system that is used by the South African Roads Agency Limited. The reasons why the system was adopted was outlined and the systems defect based methodology was briefly explained. An example was given of a completed inspection sheet used by a bridge inspector as well as an example of output from the BMS condition module. The method of identification of projects was discussed as was some budgeting, design and construction problems encountered. The use of bridge performance indices was discussed with particular reference to the Average Bridge Condition Index (ABCI), the Weighted Bridge Condition Index (WBCI) and the Bridge Condition Exposure (BCE). An example was given of how the indices were calculated. Finally some unique bridge problems encountered in South Africa were outlined.

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