SARF
better roads
Bridge Inspection Course
OVERVIEW OF STRUCTURES MANAGEMENT SYSTEMS
CSIR
Touching lives through innovation

Need for Asset Management:
Infrastructure assets have a finite life and deteriorate over time

Infrastructure assets need maintenance

Source: L Kannemeyer, SANRAL

Bridges deteriorate

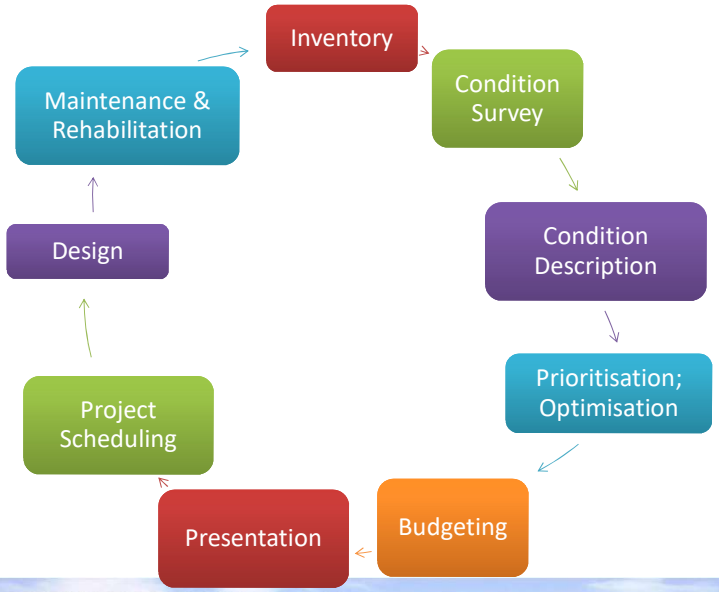
Bridges are damaged

Bridges failures do occur

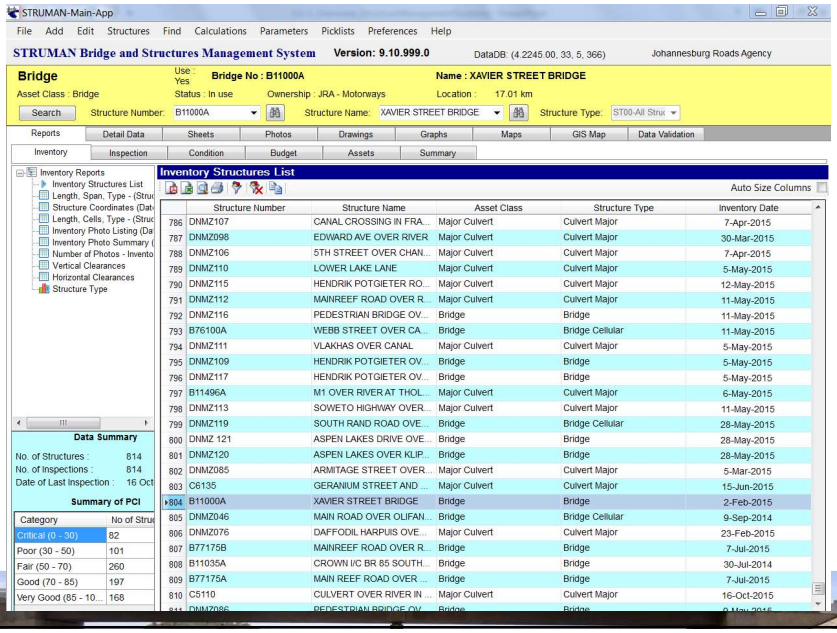
Aims of Bridge Management

- Identify and repair defects which have a direct consequence on the structural integrity of the structure and where the safety of users are at risk
- Optimise and prioritise all remedial work activities required to repair the above identified defects given a limited budget
- Obtain knowledge of current state and value of structures
- Obtain historical records of spending, repairs and strengthening of structures
- Obtain knowledge on deterioration rates of structures for corrective action to be taken, thus preventing future failures
- Obtain adequate warning before serious failures occur
- Enable future budget forecasting
- Compile detailed and summarized reports

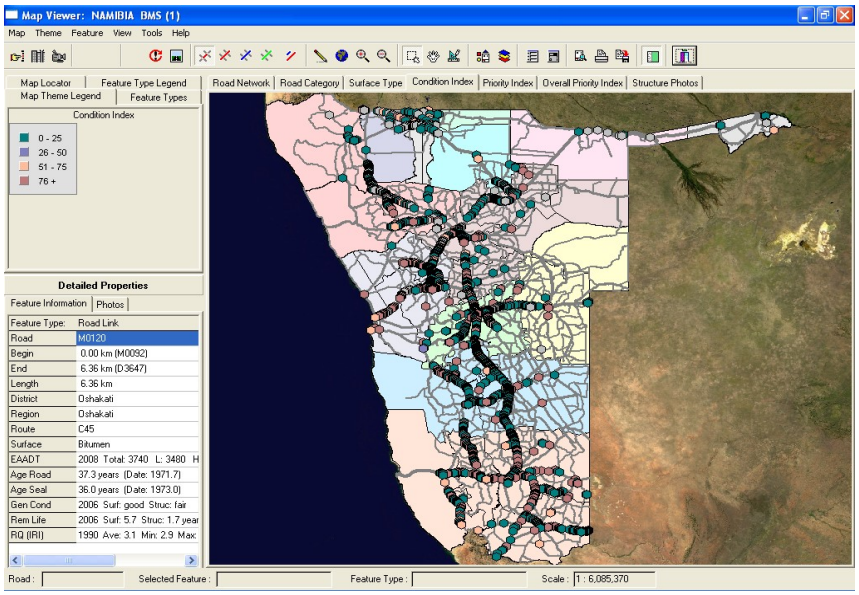
Activity flow in a BMS



Inventory



Inventory



Inventory Information: Bridges

- Bridge type;
- Number of spans;
- Number of piers;
- Number of abutments;
- Number of arches;
- Number of cable groups;
- Overall structure length;
- Overall structure width;
- Total deck area;
- Maximum pier height;
- Maximum abutment height;
- Minimum width of roadway between kerbs;
- Paved width of approach road;
- Minimum vertical clearances; and
- Angle of skew

Inventory Information: Major Culverts

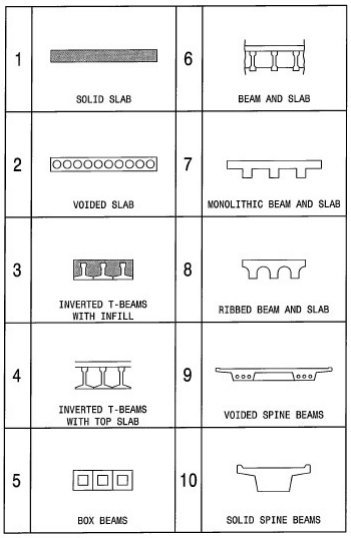
- Number of cells;
- Overall structure length;
- Overall structure width;
- Maximum Cell Size: Width;
- Maximum Cell Size: Height;
- Total opening area;
- Average cell length;
- Maximum height of fill;
- Total plan area;
- Minimum width of roadway; and
- Paved width of approach road.

15

Detail Inventory

- Inventory Module
  - Location Details - (JORA)
  - Coordinates
  - Classification - Bridge
  - Location Features
  - Contract Details
  - Dimensions, Geometry and Road Clearances - Bridge
  - Structural Features - Bridge
    - Deck - Bridge
    - Bearings - Bridge
    - Expansion Joints - Bridge
    - Piers - Bridge
    - Abutments - Bridge
    - Wings/Retaining Walls - Bridge
    - Embankment Protection - Bridge
  - Design Characteristics - Bridge
  - Hydraulic Data - Bridge
  - Drainage - Bridge
  - Factors Influencing Field Inspection - Bridge
  - Services
  - Road Clearances
  - Road Configuration, Traffic Volumes and Surfacing
  - Maintenance History
  - Maintenance Agreements and Responsibilities
  - Widening, Strengthening and Retrofitting
  - Additional Remarks
  - Photo Details - Inventory
  - Drawings Details

DECK TYPE

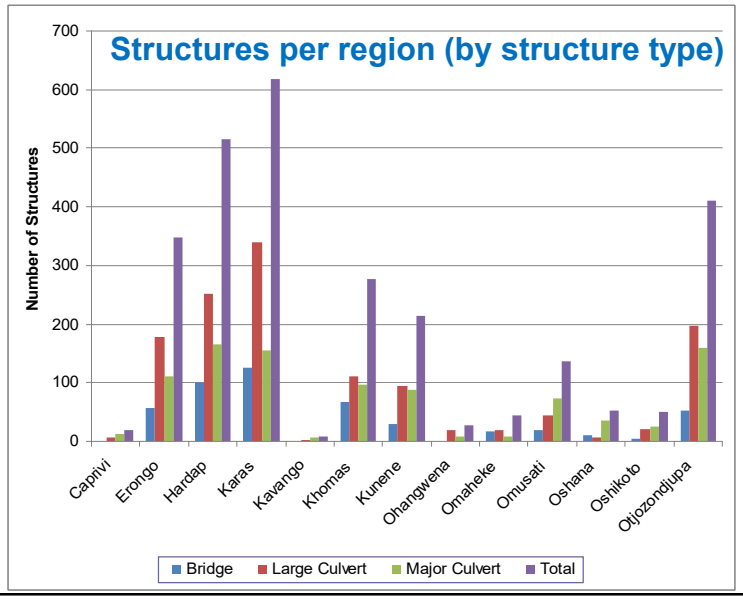


Summary of Inventory

Number of structures per maintenance region (by structure type)

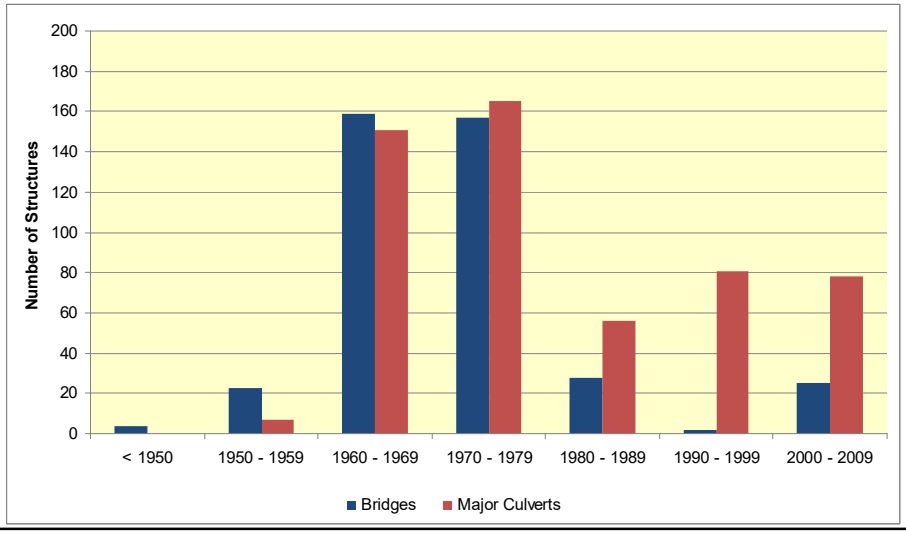
Structure Type	Maintenance Region				Namibia
	Keetmanshoop	Oshakati	Otjiwarongo	Windhoek	
Bridge	164	36	113	170	**483**
Major Culvert	211	165	307	264	**947**
Large Culvert	444	113	426	307	**1 290**
Total	**819**	**314**	**846**	**741**	**2 720**

Summary of Inventory

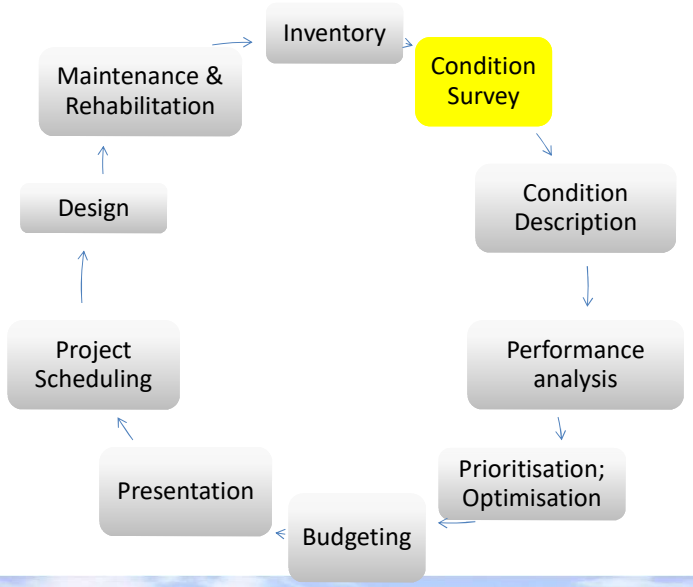


Summary of Inventory

Age distribution of structures



Activity flow in a BMS



Condition Survey

- Survey is required to identify **defects** on structures
- **Defects** are rated in terms of degree, extent and relevancy (DER)
- Rating should accurately represent the effect of the **defect** on the structural integrity of the structure
- It should also represent the effect of the **defect** on safety of the user and the serviceability of assets
- Survey should be systematic to ensure all **defects** are recorded

Examples of Defects

- Spalling
- Scour
- Erosion
- Settlement
- Honeycombing
- Defective drains
- Defective surfacing
- Rotating abutments
- Defective guardrails
- Cracks - bending, shear,...
- Insufficient cover to reinforcement
- Excessive deflections
- Expansion joints not watertight
- Defects on concrete surface
- Flood debris accumulation

Bridge Inspector

- Qualified
- Experienced
- Trained
- Good understanding of structural behaviour
- Attention to detail

COTO Accreditation Requirements

- Accreditation requirements include:
  1. Qualifications;
  2. Experience; and
  3. Training.
- **Individuals** are accredited and not consulting engineering firms.
- Only inspectors whose accreditation is valid and up to date will be allowed to carry out visual assessments of road structures.

Types of Inspectors

- Bridge Inspector
- Senior Bridge Inspector
- Major Culvert Inspector

Qualifications and Experience

- Bridge Inspector:
  - Professional engineer with a minimum of 5 years bridge and culvert design experience obtained during the previous 20 years; or
  - Professional Technologist with a minimum of 10 years bridge and culvert design experience obtained during the previous 20 years.

Qualifications and Experience

- Senior Bridge Inspector
  - Professional engineer with a minimum of 15 years full time bridge design experience accumulated over the previous 25 years.
  - Ideally such a candidate will be in a senior position and view bridges as their full time occupation.
  - Candidate must have design experience in continuous prestressed concrete bridges.

Qualifications and Experience

- Major Culvert Inspector
  - A qualified technician, technologist or engineer with a minimum of 5 years bridge and culvert design experience obtained during the previous 12 years.
  - Other structural design experience will also be considered.

Experience Requirements

- Valid experience means personal design experience and does not include signing off designs done by others.

Training

- Inspectors must undergo training before being accredited.
- Subjects to be covered in the training:
  - An overview of the objectives of the visual assessment of structures;
  - A brief description of the data processing procedures and applications of the final results;
  - An in-depth explanation of the DER methodology of assessment,
  - Descriptions of various types of distress and ratings for each type;

Accreditation

- Accreditation is done by a sub-committee of the COTO Structures Committee

Attendance of training and passing of the written and practical tests do not automatically lead to accreditation

Types of Bridge Inspection

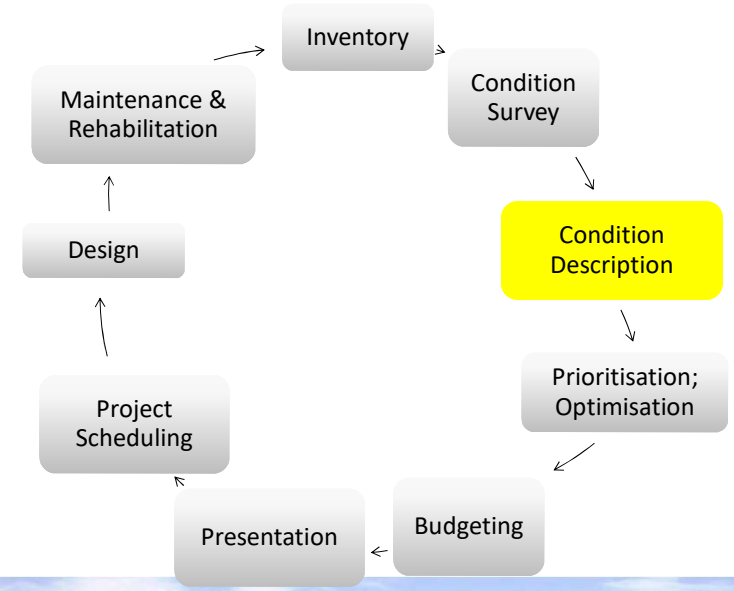
- Network Level Inspections
  - Visual inspections in accordance with field inspection sheets
  - Principal inspections
  - Partial inspections
  - Completion inspections
- Project Level Inspections
  - More detailed inspection of structures identified through the network level inspections in need of maintenance or repairs
  - May involve diagnostic surveys and destructive testing
  - Lead to designs, tender documents and drawings for maintenance or repair contracts

The DER Rating System

D = DEGREE of defect	How bad or severe is the defect
E = EXTENT of defect	How common is the defect on the inspection item being inspected
R = RELEVANCY of defect	Considers the consequences of defects with regard the **structural integrity** of the structure or the **safety of the user**

34

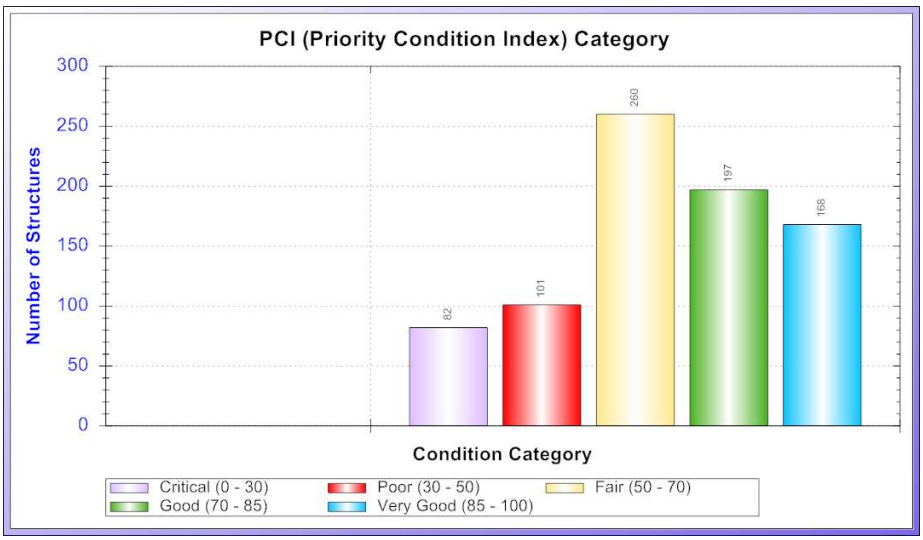
Activity flow in a BMS



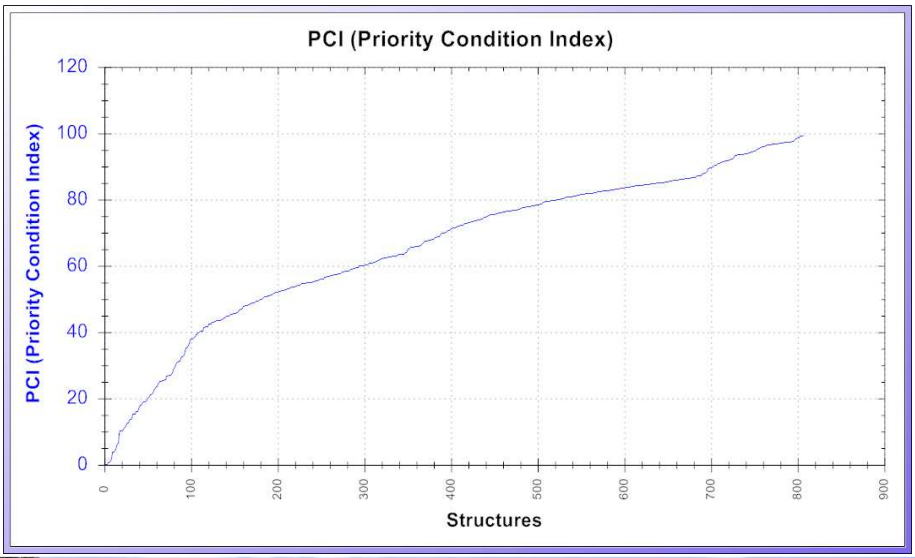
Priority Condition Index (PCI)

The PCI value is intended to identify those structures with the **highest priority** for maintenance or repairs by ensuring that structures with **significant defects** on vital structural elements are allocated a low PCI value (“get to the top of the list”)

Condition Description



Condition Description



Prioritisation

- Prioritisation is required to rank structures in a network for maintenance, repair and rehabilitation activities
- Structures with the greatest need for repair should be given the highest priority
- Structures are prioritised using the Priority Condition Index (PCI)
- PCI is a function of the D, E & R ratings
- Prioritisation is secondary to optimisation process

Prioritisation

Indices and Ranking Structure List

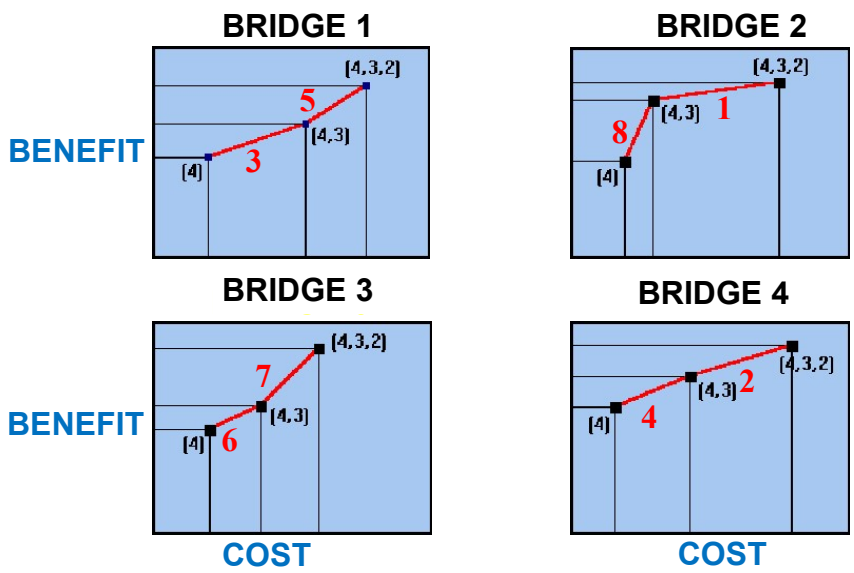
Auto Size Columns

	Structure	Structure Name	Asset Class	Structure	Inventory Date	Analysis Date	PCI (Priority Condition	PCI Rank
1	B7965	BRYANSTON D...	Bridge	Bridge	29-Apr-2014	1-Aug-2016	0.00	1
2	DNMZ083	MOPHIRING ST...	Major Culvert	Culvert Major	6-Mar-2015	1-Aug-2016	0.00	2
3	B76275A	PAARLSHOOP ...	Bridge	Bridge Cellu...	25-Feb-2014	1-Aug-2016	0.00	3
4	B5185	PEDESTRIAN ...	Bridge	Bridge	22-Sep-2014	1-Aug-2016	0.00	4
5	B77360A	ELOFF STREE...	Bridge	Bridge	5-Feb-2014	1-Aug-2016	0.62	5
6	C7575	KILLARNEY G...	Major Culvert	Culvert Major	12-Mar-2015	1-Aug-2016	0.65	6
7	C7815	CORK AVENUE...	Major Culvert	Culvert Major	20-May-2014	1-Aug-2016	0.77	7
8	C7700	PIERRE ROAD ...	Major Culvert	Culvert Major	28-Aug-2014	1-Aug-2016	1.10	8
9	B6540	KING GEORGE...	Bridge	Bridge	25-Feb-2015	1-Aug-2016	1.89	9
10	B76525A	HARRISON ST...	Bridge	Bridge	8-Jun-2015	1-Aug-2016	3.80	10
11	DNMZ03	BIRD STREET ...	Bridge	Bridge	25-Feb-2014	1-Aug-2016	3.81	11
12	C7825	HONEYBALL A...	Major Culvert	Culvert Major	11-Aug-2014	1-Aug-2016	3.91	12
13	DNMZ102	MAXWELL STR...	Major Culvert	Culvert Major	31-Mar-2015	1-Aug-2016	4.36	13
14	C7800	GERTRUDE S...	Major Culvert	Culvert Major	6-Mar-2014	1-Aug-2016	4.47	14
15	C7535	WABORD ROA...	Major Culvert	Culvert Major	1-Apr-2015	1-Aug-2016	5.61	15
16	C5120	LEVEL PEDES...	Major Culvert	Culvert Major	4-Aug-2014	1-Aug-2016	6.10	16
17	B5155	BRIDGE OVER...	Bridge	Bridge	7-Aug-2014	1-Aug-2016	6.49	17
18	JGUN13	WILLIAM NICO...	Major Culvert	Culvert Major	27-Nov-2014	1-Aug-2016	9.39	18
19	DNMZ050	SHAKESPEAR ...	Major Culvert	Culvert Major	22-Sep-2014	1-Aug-2016	10.12	19
20	DNMZ103	HAY & LONG O...	Major Culvert	Culvert Major	31-Mar-2015	1-Aug-2016	10.13	20
21	UNK25	BRIDGE STRE...	Bridge	Bridge Cellu...	11-Sep-2014	1-Aug-2016	10.15	21
22	B6615	CLAIM STREE...	Bridge	Bridge	25-Feb-2015	1-Aug-2016	10.32	22
23	C5100	PEDESTRIAN ...	Major Culvert	Culvert Major	26-Jan-2015	1-Aug-2016	10.70	23
24	B11265A	ALBERTINA SI...	Bridge	Bridge	26-Feb-2015	1-Aug-2016	10.98	24
25	B76660A	LOUIS BOTHA ...	Bridge	Bridge	6-Nov-2014	1-Aug-2016	11.36	25
26	DNMZ084	ARMITAGE ST...	Major Culvert	Culvert Major	5-Mar-2015	1-Aug-2016	11.77	26

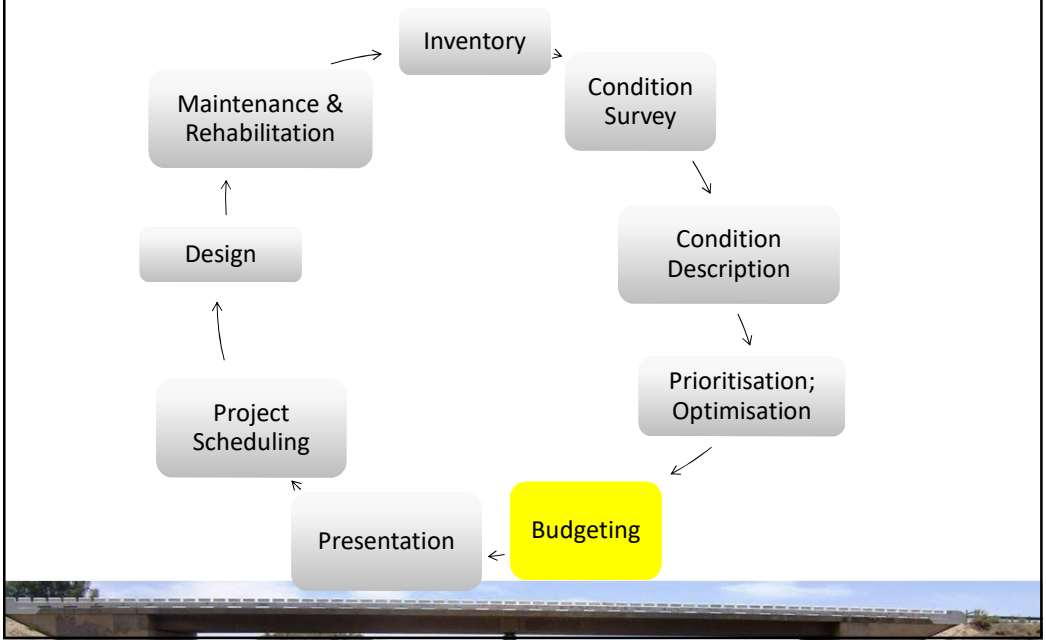
Optimisation

- Maximum **risk reduction** with available funds
- Based on the **benefit to cost ratio**
- Benefit = risk reduction
- **Risk** is directly related to the **relevancy factor R**
- **Costs** are calculated for each **remedial work item** allocated to each defect
- Given a **limited budget** remedial work items with the greatest cost but with the smallest R value will be first removed from the budget

Optimisation



Activity flow in a BMS



Budgeting

SPANS									
	18 Longitudinal Members			19 Transverse Members			20 Decks & Slabs		
	D	E	R	D	E	R	D	E	R
S1	X			X			3	2	3

Item	Pos	Activity	Qty	Unit	U	MS	Remarks	Mon Fr.	Photo No's
20	S1	20.120 Seal Cracks	5	m	2		Cracks at deck seatings		S04
20	S1	20.118. Repair spall (including honeycombing)	20	L	4		Rebar to be repaired as well		S02, S03
20	S1	20.654. Access-using scaffold (< 10 m)	1	No	4				S02, S03
20	S1	20.702. Traffic accommodation-Low (< 10 000 vpd)	1	No	4				S02 S03

Inspectors Assessment of Structure condition and further comments

1. Increase vertical clearance to 5,2m by lowering road
2. Suggest placing of guardrails to protect pedestrians

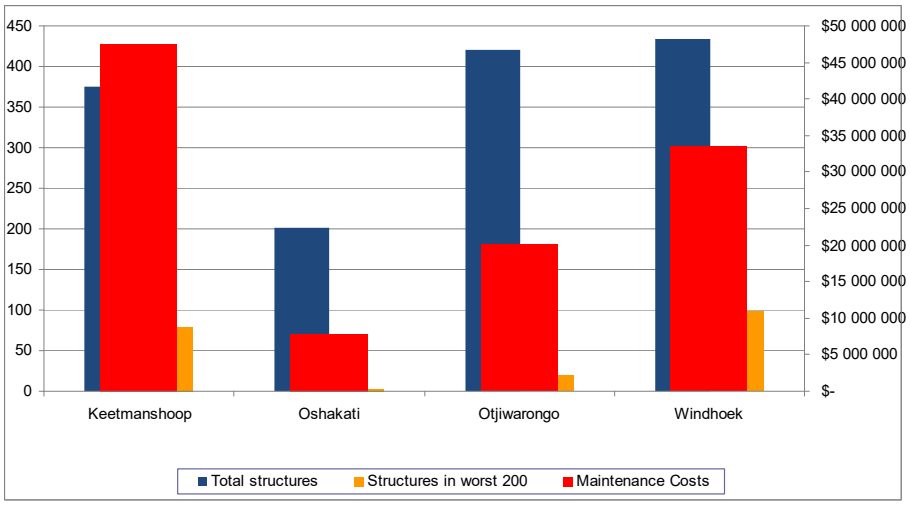
Budgeting

Budget Repair Cost Structures List

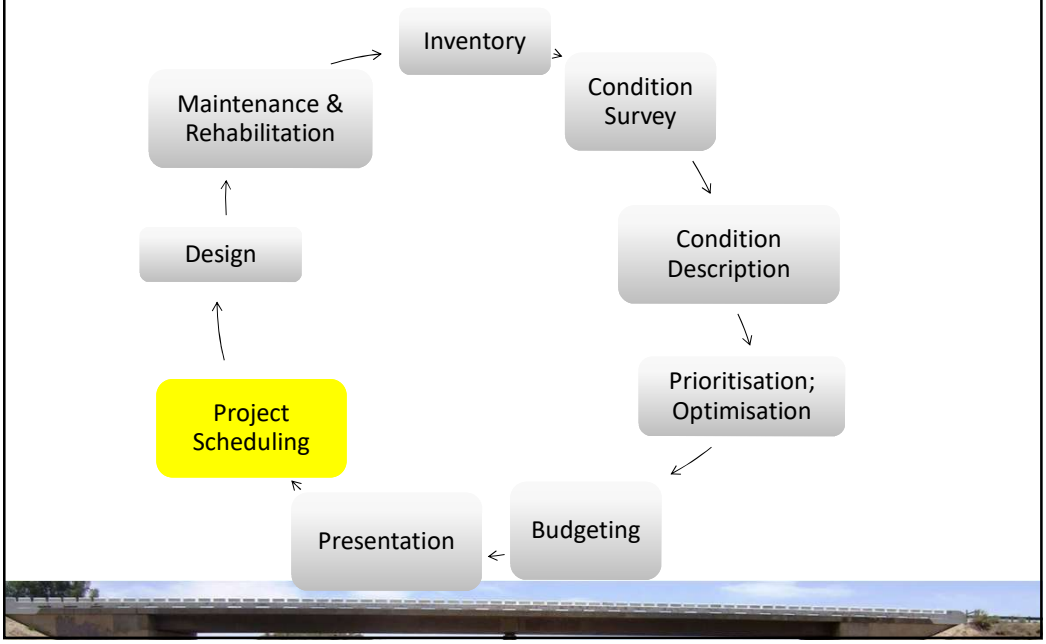
Auto Size Columns

	Structure	Structure	Asset Class	Structure	Inventory	Inspection	Total Cost	Budget Year	Year 2	Year 3
1	B8065	RIDGEWAY...	Bridge	Bridge	30-Apr-2014	30-Apr-2014	268 400	231 820	0	36 580
2	B8035	8TH AVENU...	Bridge	Bridge	25-Sep-2014	25-Sep-2014	197 130	195 360	0	1 770
3	B8090B	FOURWAY...	Bridge	Bridge	22-Jul-2014	22-Jul-2014	90 130	78 880	0	11 250
4	C5240	VUNDLA D...	Major Culvert	Culvert Major	19-Nov-2014	19-Nov-2014	64 180	64 180	0	0
5	B8305	PEDESTRI...	Bridge	Bridge	15-Oct-2014	15-Oct-2014	52 270	52 270	0	0
6	C5200	BRIDGE O...	Major Culvert	Culvert Major	28-Oct-2014	28-Oct-2014	54 499	50 074	0	4 425
7	B8310	REPUBLIC ...	Bridge	Bridge	17-Jan-2014	17-Jan-2014	49 217	47 360	0	1 857
8	B7900	MANGAAN ...	Bridge	Bridge	15-Jan-2014	15-Jan-2014	82 650	39 590	0	43 060
9	C5100	PEDESTRI...	Major Culvert	Culvert Major	26-Jan-2015	26-Jan-2015	38 690	38 690	0	0
10	C5145	PEDESTRI...	Major Culvert	Culvert Major	13-Aug-2014	13-Aug-2014	78 350	37 050	0	41 300
11	C5235	STONE CU...	Major Culvert	Culvert Major	19-Nov-2014	19-Nov-2014	83 615	29 640	0	53 975
12	B8020	12TH AVEN...	Bridge	Bridge	17-Apr-2014	17-Apr-2014	77 307	19 740	2 940	54 627
13	C5255	PEDESTRI...	Major Culvert	Culvert Major	6-Oct-2014	6-Oct-2014	21 250	18 890	0	2 360
14	B7965	BRYANSTO...	Bridge	Bridge	29-Apr-2014	29-Apr-2014	693 750	15 870	547 830	130 050
15	C5210	WOODEN ...	Major Culvert	Culvert Major	12-May-2015	12-May-2015	15 735	14 260	0	1 475
16	C5120	LEVEL PED...	Major Culvert	Culvert Major	4-Aug-2014	4-Aug-2014	13 970	13 380	0	590
17	B7945	JACARAND...	Bridge	Bridge	15-Jan-2014	15-Jan-2014	22 300	12 870	2 470	6 960
18	C5230	PIPED CRO...	Major Culvert	Culvert Major	25-Nov-2014	25-Nov-2014	227 720	11 800	0	215 920
19	B7955	12TH AVEN...	Bridge	Bridge	17-Apr-2014	17-Apr-2014	91 570	8 060	0	83 510
20	C5140	PEDESTRI...	Major Culvert	Culvert Major	13-Aug-2014	13-Aug-2014	24 780	5 900	0	18 880
21	C5165	PEDESTRI...	Major Culvert	Culvert Major	28-Jul-2014	28-Jul-2014	6 160	3 745	0	2 415
22	B7810	C R SWAR...	Bridge	Bridge	29-Sep-2014	29-Sep-2014	13 960	3 540	8 850	1 570
23	B7790	RABIE ROA...	Bridge	Bridge	6-Mar-2014	6-Mar-2014	6 718 090	2 950	0	6 715 140
24	B7895	PLATINA S...	Bridge	Bridge	15-Jan-2014	15-Jan-2014	73 210	1 770	53 100	18 340
25	JG4372	Main Road ...	Bridge	Bridge	19-Mar-2015	19-Mar-2015	58 410	1 470	0	56 940

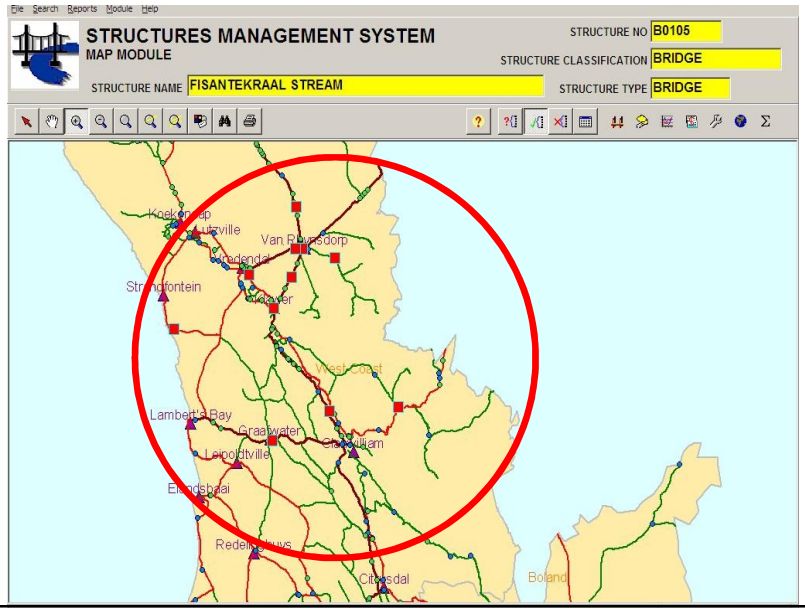
Estimated Structure Maintenance Costs



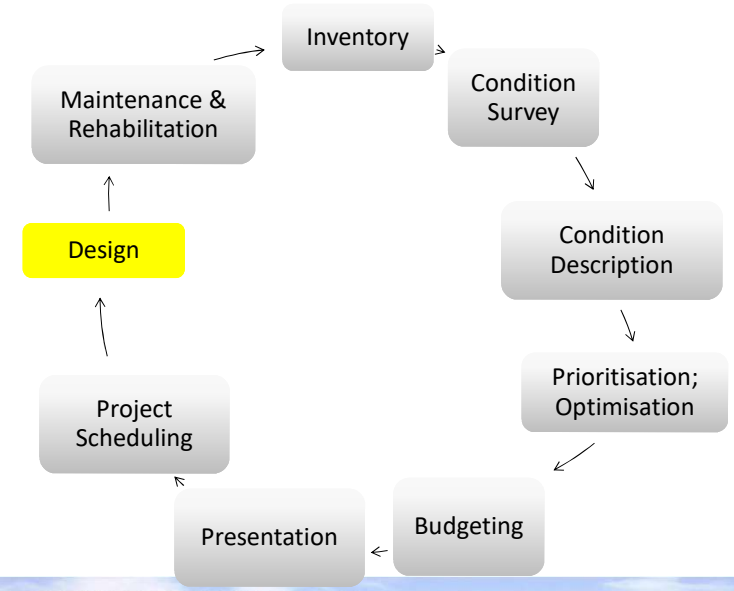
Activity flow in a BMS



Project Scheduling



Activity flow in a BMS



Survey & Testing of Surface Concrete

- Determination of concrete cover to reinforcement, carbonation depth and chloride content within the surface layer and surface hardness of a concrete member.
- Concrete cover is determined by an electromagnetic covermeter. The covermeter shall be calibrated before using on site. The validity of results obtained from the covermeter survey shall be checked by direct measurement to exposed reinforcing bars.

Measurement of Carbonated Depth

Freshly exposed concrete

Phenolphthalein indicator

Determining Surface Hardness

Surface Hardness is determined using Schimdt Hammer, developed in 1948 by a Swiss Engineer, Ernst Schimdt. The device consists of a spring-controlled mechanism housed in a tubular frame and works by the rebound principle.

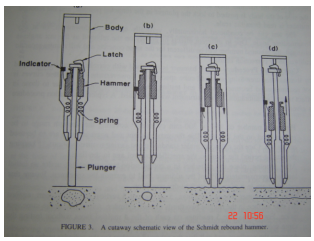
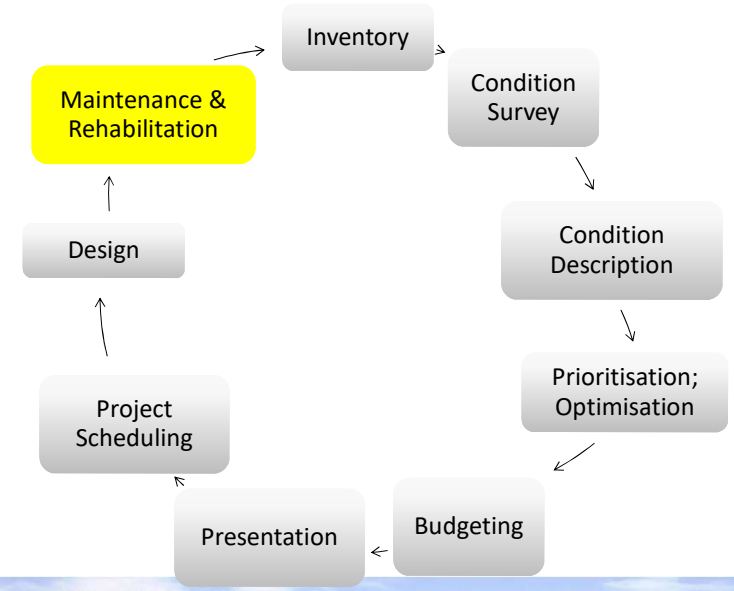


FIGURE 3. A cutaway schematic view of the Schmidt rebound hammer.

Type N

Activity flow in a BMS



Maintenance and Rehabilitation

Maintenance and Rehabilitation

Completed Repair

“Close the Loop”

- Update inventory to reflect any changes to the structure
- Carry out a completion inspection (principal inspection) of the repaired structure
- Update condition data for structure in BMS

Benefits of a BMS

- Structures are maintained at acceptable levels of service
- Defects are identified timely and repaired economically
- Prioritisation and optimisation of work (expenditure) can be done
- Funds are channelled to the correct structures
- Improved control of expenditure by management
- Accessibility of information
- Decision making easier (test impact of decisions)
- Detail of output depends on user

Conclusions

- A good asset management system is one
  - That is used by and meets the needs of all levels of management
  - Achieves the primary purpose that defects are identified and repaired
  - Ensures that the safety of the user is maintained at all times
- Well maintained assets encourage public interest and appreciation with regards their contribution to the beauty of our environment.