2 MANAGEMENT OF INSPECTION AND MAINTENANCE

2.1 GENERAL ADMINISTRATION AND MANAGEMENT SYSTEMS

Bridges are valuable assets which cannot be built and then forgotten. Asset management practices need to be implemented by road controlling authorities to achieve target levels of service in the most cost-effective manner. The inspection and maintenance programme allows the bridge stock condition and performance to be better understood so that overall maintenance and development strategies can be implemented. It is usual for the Bridge Inspection Engineer (TNZ S6, 2000) to be responsible for the overall asset management of the bridge stock and the setting of individual bridge strategies.

Defects requiring attention will develop during a bridge's life. It is important that these defects are identified at an early stage to:

- Ensure public safety;
- Protect the investment by extending the life of the structure, in a manner consistent with the individual bridge strategy;
- Minimise the cost of repairs.

Efficient and effective procedures are required to ensure:

Consistency and uniformity in inspections, so that remedial work can be correctly prioritised;

- Use of sound assessment techniques;
- Use of effective repair methods;
- Feedback is provided to designers.

When a large bridge stock is to be managed and a number of inspection teams used it is more difficult to ensure consistency of inspection and prioritisation of repair work. In these cases the Bridge Inspection Engineer, or for Transit New Zealand, the National Bridge Consultant, needs to undertake regular auditing and review and if necessary implement training to ensure consistency is achieved. Particular care is needed when inspection and maintenance management services are contracted out.

2.2 RECORD SYSTEMS AND REPORTING

The success of any bridge inspection and maintenance programme depends on its reporting system, as this is the means by which items identified in inspections are included in budgets and repair work is undertaken.

Accurate record-keeping enables the Bridge Inspection Engineer to:

- Programme maintenance work;
- Assess structural adequacy and provide information for assessment of load-carrying capacity, which ensures that posting and overweight permit structural details are accurate and up to date;
- Monitor the progress of structural changes;
- Provide feedback to designers.

The form of recording system used needs to be designed to suit local conditions. There is no benefit in wasting time and money having one that is too elaborate and provides data that are not going to be used.

Records should consist of all of the following, in whatever form is most convenient:

- Bridge inventory (either computer-based or manual file);
- As-built drawings and photos;
- File of inspection forms, reports, photos and diagrams;
- File of remedial work, records, photos and costs.

A computer-based system can be an efficient way to store, update and manipulate data, particularly for a large number of structures. Data can be entered directly onto a laptop during the inspection.

To ensure consistency in reporting, a standard inspection form (such as TNZ 801, see Appendix 13.3) or standard inspection procedure should be used, as this provides a check list when collecting data on site. It is also important to use a reference system which allows defects to be located in the future for monitoring or repair.

Copies of completed inspection reports, together with supplementary reports and photographs or line diagrams to identify defects, should be held on file to provide a continuous history of the condition of each bridge structure.

2.3 PROGRAMMING OF INSPECTIONS AND MAINTENANCE

The various categories and frequencies of inspection are set out in Bridge Inspection Policy (TNZ S6, 2000). See Appendix 13.3.

Programming of inspection and maintenance work enables co-ordination of manpower (including specialist personnel) and equipment.

Environmental factors such as tides and river levels may need to be taken into account, as may traffic volumes.

Superficial Inspections are required at frequent intervals and should be programmed alongside other regular maintenance and inspection work required for the rest of the roading network.

An overall programme for General and Detailed Inspections (required at 2-yearly and 6-yearly intervals respectively) should be prepared for a period of ten to twelve years. While for most bridges it is appropriate to use the 2-year inspection interval some bridges (e.g. those that are posted) may require more frequent inspection and this should be programmed. This programme should include details such as the name and location of the structure, date and type of last inspection and date and type of proposed inspections (see Figure 2.1 for an example). Bridge maintenance programming usually requires design and planning work to be undertaken in the winter for summer construction, and hence if bridge inspection staff are involved in this work the inspections may be limited to the spring and autumn.

From this, a detailed programme of inspections can be produced for a particular year (see Figure 2.2). A detailed inspection programme must be flexible enough to accommodate availability of resources and access.

Those Special Inspections which are required after specific events such as earthquakes or flooding obviously cannot be programmed in advance but must be fitted in to the programme as they occur.

Access plays a large part in inspecting and maintaining some structures, both in cost and time. However, it is important that adequate and safe access is provided, because if access is poor the quality of the inspection will suffer. Areas with most difficult access may be the most important to inspect and maintain. If inspection involves use of special access equipment such as a hydraulic platform, it may be possible to reduce hire charges by inspecting as a group all the bridges that require the equipment.

A programme of maintenance work is based on those items identified in the inspections, in priority order, together with other routine tasks such as maintaining drainage, replacing damaged traffic barriers etc. As the amount of work will not be known until after inspection, the programme needs to be flexible. It is important to follow up the maintenance work to ensure that defects identified have been attended to.

SH	NAME	RP	TYPE	FISCAL YEAR												LAST INSPECTION	
				88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	DATE	TYPE
	Bridge 1		C	D		X		X		D		X		X		'88	D
	Bridge 2		T	D	E	E	E	E	E	D	E	E	E	E	E	'89	E
	Bridge 3		C	D		X		X		D		X		X		'88	D
	Bridge 4		C	X		D		X		X		D		X		'88	X
	Bridge 5		S	X		D		X		X		D		X		'88	X
	Bridge 6		C	X		D		X		X		D		X		'88	X
	Bridge 7		C	X		D		X		X		D		X		'88	X
	Bridge 8		C		D		X		X		D		X		X	'89	D
	Bridge 9		C		D		X		X		D		X		X	'89	D
	Bridge 10		S		D		X		X		D		X		X	'89	D
	Bridge 11		S	X		X	D		X		X		D		X	'88	X
	Bridge 12		T	E	E	E	D	E	E	E	E	E	D	E	E	'89	E
	Bridge 13		C		X		D		X		X		D		X	'89	X
	Bridge 14		C	X		X		D		X		X		D		'88	X
	Bridge 15		C	X		X		D		X		X		D		'88	X

X - General inspection (2 yearly)   D - Detailed inspection (6 yearly)   E - Special inspection (Annual)

Inspections will be carried out AUTOMATICALLY after Heavy Flooding and Earthquakes.   Type: C - Concrete, S - Steel, T - Timber

Figure 2.1: Typical long-term inspection programme.

SH	NAME	RP	TYPE	FISCAL YEAR 1990/91												LAST INSPECTION	
				JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	DATE	TYPE
	Bridge 1		C										XXXXXXXXX			'88	D
	Bridge 2		T										EEEEEEEEE			'89	E
	Bridge 3		C										XXXXXXXXX			'88	D
	Bridge 4		C										DDDDDDDDD			'88	X
	Bridge 5		S										DDDDDDDDD			'88	X
	Bridge 6		C										DDDDDDDDD	DDDDDDDDD		'88	X
	Bridge 7		C										DDDDDDDDD			'88	X
	Bridge 8		C													'89	D
	Bridge 9		C													'89	D
	Bridge 10		S													'89	D
	Bridge 11		S				XXXXXXXXX									'88	X
	Bridge 12		T				EEEEEEEEE									'89	E
	Bridge 13		C													'89	X
	Bridge 14		C			XXXXXXXXX										'90	X
	Bridge 15		C			XXXXXXXXX										'90	X

X - General inspection (2 yearly)   D - Detailed inspection (6 yearly)   E - Special inspection (Annual)

Inspections will be carried out AUTOMATICALLY after Heavy Flooding and Earthquakes.   Type: C - Concrete, S - Steel; T - Timber

Figure 2.2: Typical detailed inspection programme.

2.4 ORGANISATION OF PERSONNEL

Table 1 of TNZ S6 "Bridge Inspection Policy" identifies the personnel involved in bridge inspections.

It is important that inspectors be competent and experienced because bridge maintenance will be based on their findings.

Inspection tends to be repetitive by nature, so staff need to be methodical and able to spot small changes in a structure.

Ideally all inspections should be carried out by the same staff. This ensures consistency and enables comparisons with previous inspections and with other structures so that changes in the structure's condition can be monitored and priorities for remedial work established.

Because inspection staff work in remote areas and often alone they must have a communication system that operates throughout the inspection area. They must be familiar with the physical hazards and traffic control required or off-road parking available at each site. If staff are in the field for an extended period then additional communication, such as a daily faxed report, is desirable. Staff need to be aware of the health and safety issues and take a responsible attitude to them.

2.5 REGULATORY ISSUES

All staff involved in inspecting and specifying, managing and carrying out maintenance and repair work need to be aware of their obligations and liabilities under the Resource Management Act (1991) the Health and Safety in Employment Act (1992) and the Building Act (1991).

2.6 FINANCIAL CONTROL

2.6.1 Preparation of Funding Request

It is important to identify and work to priorities, particularly where there is a shortage of funds.

For routine maintenance work (such as cleaning drains and joints, and painting handrails etc), it is usual practice to base the funding request on historical expenditure.

For structural maintenance work (such as joint and bearing repairs or replacement and major repaints etc) it is usual practice to prioritise the work as high, medium or low priority on a job by job basis, and to seek funding for all high-priority jobs and a proportion of medium priority jobs.

2.6.2 Monitoring of Expenditure

Once the budget has been set it is important to monitor actual expenditure against budget. This can be done by preparing a monthly expenditure forecast and comparing monthly:

- Actual costs against forecast, and
- Forecast expenditure against budget.

Comparisons can be by spreadsheet (as shown in Figure 2.3) or by graphical means.

At the beginning of the financial year the forecast expenditure would equal the budgeted amount. However, if during the year the forecast expenditure is predicted to exceed the budget, additional funds should be sought or lower priority work deferred. If the forecast expenditure is predicted to be less than the budget, lower priority work can be advanced or the surplus declared.

2.7 THE INSPECTION PROCESS

The general inspection procedures, personnel, equipment and techniques are covered in a number of manuals specifically devoted to the subject. A list is given in the Bibliography (Section 2.10), and the reader is recommended to study one or more of them.

2.8 FEEDBACK TO DESIGNERS

Often designers are unaware of problems in the field so it is important that there is a transfer of information between inspectors, designers, and owners to ensure that sound techniques are promoted and poor experiences highlighted so that problems are not perpetuated.

Identifying areas for better design and detailing should result in better performance and durability of future bridge structures. Thus the Bridge Inspection Engineer should ensure that inspection reports include comments on design performance where relevant, and should pass these comments to designers.

Forecast vs Expenditure 1990 / 91

($ 000)

Item No.	Description *	Apr	May	June	July	August	September	October	November	December	January	February	March	Expend Prev.Yr.	Allocation This Yr.	Forecast This Yr.
	MAINTENANCE.															
	Bridge 1: Forecast.	11.16	24.17	40.91	59.50	76.24	98.55	113.43	128.31	143.18	158.06	171.07	185.95		185.95	185.95
	Actual.	11.98	25.42	42.41	59.94	75.69	98.22	113.19	124.52	139.75	146.84	157.00	183.80			
	Bridge 2: Forecast.	0.00	0.00	11.00	11.00	11.00	22.00	22.00	22.00	36.00	36.00	36.00	45.20		45.20	45.20
	Actual.	0.00	0.00	0.00	8.74	8.74	8.74	8.74	8.74	17.47	17.47	17.47	30.62			
	Bridge 3: Forecast.	3.60	7.32	10.98	14.64	18.30	21.96	25.62	29.28	32.94	36.60	40.26	44.00		44.00	44.00
	Actual.	0.00	0.00	5.80	5.80	5.80	23.68	23.68	23.68	23.68	23.68	23.68	24.86			
	Bridge 4: Forecast.	18.40	55.20	92.10	128.90	165.70	202.50	239.40	276.20	235.00	270.00	305.00	340.00		441.90	340.00
	Actual.	0.24	53.80	88.31	100.49	124.60	139.84	186.07	200.88	211.57	227.13	254.40	321.17			
	Bridge 5: Forecast.	11.98	25.42	42.99	61.39	77.14	101.46	116.43	127.76	143.87	150.96	161.12	189.35		0.00	189.35
	Actual.	2.20	6.25	11.41	15.45	19.50	24.65	28.70	32.75	30.39	34.26	38.13	42.92			
	Bridge 6: Forecast.	11.52	24.91	43.11	62.07	79.17	102.95	118.19	133.43	150.08	165.32	178.70	194.87		204.17	194.87
	Actual.	11.98	25.42	42.99	61.39	77.14	101.46	118.55	129.88	145.99	154.81	164.97	186.86			
	Bridge 7: Forecast.	9.10	27.30	45.40	63.60	81.60	99.90	118.10	136.30	154.40	172.60	250.00	255.00		220.20	255.00
	Actual.	3.77	28.35	52.34	66.77	81.21	92.01	110.08	122.83	137.53	243.08	243.79	246.54			
	Bridge 8: Forecast.	8.20	24.70	41.20	57.70	74.20	90.70	107.20	123.70	140.20	156.70	173.20	198.60		198.60	198.60
	Actual.	22.20	30.90	46.36	73.47	90.17	108.54	125.27	138.47	144.91	154.61	170.00	171.10			
	Bridge 9: Forecast.	4.70	14.00	23.40	32.80	42.10	51.50	60.80	70.20	79.50	88.90	98.30	125.00		112.30	125.00
	Actual.	0.00	7.68	42.12	43.50	46.35	48.73	81.80	85.25	89.96	105.14	106.50	126.24			
	Bridge 10: Forecast.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	1.60	1.60	1.60	1.60		1.60	1.60
	Actual.	0.00	0.00	0.04	0.04	0.04	0.04	0.20	0.20	0.20	0.20	0.20	0.20			
	TOTAL:Forecast.	78.65 *	203.02 *	351.08 *	491.61 *	625.45 *	791.53 *	921.17 *	1048.78 *	1116.76 *	1236.73 *	1415.25 *	1579.57		* 1453.92 *	1579.57
	Actual.	52.37 *	177.83 *	331.77 *	435.60 *	529.24 *	645.91 *	796.28 *	867.20 *	941.45 *	1107.22 *	1176.13 *	1334.31		* *	

* can identify individual structures, length of road or Organisation responsible.

Figure 2.3: Typical expenditure monitoring spreadsheet.

2.9 ECONOMIC EVALUATION

2.9.1 Introduction

Economic evaluation techniques can assist decision making on many aspects of bridge maintenance and rehabilitation and ensure the most cost-effective management strategy is adopted. For instance, economic evaluation enables management to make more rational decisions about when to replace an old structure rather than persist with high-cost maintenance. It enables the comparison of a number of rehabilitation options which restore the bridge to its original level of service and extend its life. Economic evaluation also provides a means for assessing the total benefit to the land transport system (including benefits to road users) of upgrading weak links such as weight restricted bridges.

Not all aspects are covered here and some are described only briefly. More detail on economic evaluation procedures can be found in the Transfund Project Evaluation Manual (PFM2 1997).

2.9.2 Determining Priorities for the Bridge Maintenance Programme

Each item in the bridge maintenance programme should be the most cost-effective response to the maintenance need identified in the inspection. Items should only be included in the programme if they will give a future saving that exceeds the cost of the item. The method for determining this is summarised in Section 2.9.3. It is fundamental to understand why the defect has developed (outside cause, inherent design or construction problem or general deterioration) and anticipate what future changes may be likely and how quickly they might develop. Only then can repair options be identified and their effectiveness assessed. Maintenance funds should not be spent for cosmetic reasons, or where the benefit that will be achieved is less than the amount being spent. If any funds remain, after all the essential work has been budgeted for, those funds should be declared surplus.

When the budget for road works is restricted it is necessary to take the evaluation of the bridge maintenance programme one step further and determine priorities. Some items that the analysis has shown will give future savings in excess of cost must be deferred until the following year. To prioritise the bridge maintenance items, the following factors should be considered:

- Condition of the component;
- Risk to the public;
- Importance of the component;
- Importance of the bridge;
- Cost consequences of delaying the maintenance.

Priorities must be set consistently. Although a subjective decision can be made for small maintenance items, an empirical procedure based on the above factors should be implemented for larger maintenance and rehabilitation items. Transit has implemented a specific prioritisation procedure for structural maintenance items. It will be found that some items can be deferred for a year with little impact on future maintenance or rehabilitation costs. Other items, however, may need to be undertaken promptly in order to avoid much larger costs in future years.

2.9.3 Economics of Maintenance Items

Savings resulting from maintenance items should be calculated using standard Transfund or Transit evaluation parameters including:

- Discount rate of 10%;
- Evaluation period of 25 years.

Evaluation is done in constant dollars (i.e. no allowance is made for inflation).

All costs expected over the next 25 years, including that of the maintenance item itself, are listed at current prices along with the year in which they are likely to be incurred. These are obtained from historical records for the bridge concerned, and judgement about future needs, based on knowledge of the performance of other similar structures.

Every cost is then discounted using the 10% discount rate. A table of discounting factors, along with more detailed instructions on discounting can be found in the Transfund Project Evaluation Manual (PFM2 1997).

All discounted costs are then added together to give a net present value of cost for that maintenance item. This is done for each possible maintenance option (including the "Do Nothing" option).

This process is then repeated, but with the assumption that the proposed maintenance item be carried out in future years. Only routine maintenance costs are allowed for this year. If the proposed maintenance item is essential, leaving it out of the current year's programme will have consequential changes on costs in future years.

The maintenance option with the lowest net present cost is the most economically favourable option.

2.9.4 Economics of Continued Maintenance Compared with Replacement

The calculation method described above for maintenance items can also be used to compare other options such as more substantial rehabilitation or even replacement. This section considers rehabilitation or replacement options on the existing alignment which reduce future maintenance costs but offer no other benefits to road users.

The procedure and parameters to be used are the same as in Section 2.9.3. For the bridge replacement option the future costs include the cost of the new bridge in the first year, along with the greatly reduced maintenance costs that will apply over the next 25 years.

Replacement should also be compared with other options such as a minor or major rehabilitation. For a rehabilitation option, the future costs might include a substantial cost in the first year to prolong the life of the structure by a few years, and reduced maintenance costs for the next few years which then steadily increase again until the bridge is replaced. The replacement cost is included in the year in which it is projected to be necessary, and is followed for the remainder of the 25 year evaluation period by the much lower routine maintenance cost expected for the replacement bridge. If the rehabilitation will prolong the bridge life by more than 25 years then the replacement cost does not need to be considered.

The 10% discount rate required by the Transfund Project Evaluation Manual often has the effect of making rehabilitation the most economically attractive option, even if the work is only expected to extend the life of a bridge by 10 or 15 years.

Whichever option has the lowest net present value of costs is the most economically favourable option. However, other funding criteria for the particular Road Controlling Authority may dictate the final outcome.

2.9.5 Economics of Road Benefits

When a bridge is rehabilitated or replaced there are often benefits to road users in addition to the future maintenance savings for the roading authority. These benefits can tip the scales in favour of such options in preference to continued maintenance of the existing situation, even though the continued maintenance has the lowest present value of cost.

Strengthening for instance can enable a weight restriction to be lifted. This would permit more efficient freight transport on that route, and could also allow heavy vehicles to transfer from other longer routes thereby saving on vehicle operating costs and travel time costs. Rehabilitation might also reduce accident costs, for instance by widening the deck of a narrow two lane bridge.

With replacement, further benefits are possible as the new bridge can be built on a different alignment that allows travel time savings and possibly reduces the accident rate.

Methods for calculating these benefits are contained in the Transfund Project Evaluation Manual. The benefits are discounted in the same way as the costs, and given as a present value of benefits for the option. The present value of benefits is divided by the present value of costs for the option less the present value of costs for the do-minimum, as calculated earlier, to obtain the benefit/cost ratio for the proposed improvement. This is used to rank the proposed rehabilitation or replacement against other road improvement proposals.

2.9.6 Risk Assessment

In calculating costs for various options it is sometimes not possible to pin-point exactly when a particular item of expenditure such as a bridge replacement might be necessary. For instance analysis of the structure could reveal that it is likely to fail in a certain size flood or earthquake. However it is impossible to predict when such an event will occur. The solution is to estimate probabilities of its occurring in each year, and then carry out a risk assessment.

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