First International Conference on Bridge Maintenance, Safety and Management
IABMAS 2002
Barcelona, 14 – 17 July, 2002

BRIDGE MANAGEMENT IN THE NETHERLANDS; PRIORITISATION BASED ON NETWORK PERFORMANCE

H.E. Klatter[*], J.M. van Noortwijk[†], N. Vrisou van Eck[††]

[*]Ministry of Transport, Public Works, and Water Management
Civil Engineering Division
P.O. Box 20000, 3502 LA Utrecht, The Netherlands
e-mail: h.e.klatter@bwd.rws.minvenw.nl

[†]HKV Consultants
P.O. Box 2120, 8203 AC Lelystad, The Netherlands
e-mail: j.m.van.noortwijk@hkv.nl

[††]E. Horvat Consultants B.V.
P.O. Box 4177, 3006 AD Rotterdam, The Netherlands
e-mail: nicolien.vrisou.van.eck@horvat.nl

Key words: Bridge Maintenance, Maintenance Cost, Performance, Prioritisation

Abstract. *In the Netherlands the maintenance of bridges is planned by standardising the maintenance for its constituent components. These components are all characterised by their specific technical and functional properties and financial value. Standardised documents, plans and procedures were introduced for optimising maintenance of civil structures. Because the actual annual maintenance need does not fit into the annual budget in general, prioritisation of measures is necessary. The effect of this prioritisation on the network performance can be optimised using life-cycle costing techniques. Another important aspect is to qualitatively express the network performance to facilitate and assist management. Performance indicators are being developed for this purpose, based on a description of the influence of maintenance on the quality of the network in terms of the policy objectives "accessibility", "traffic safety", "environmental quality", "comfort" and "aesthetics". The cost of the maintenance programmes can be related to these objectives. The effects of the different maintenance options can be evaluated on a network level in this way.*

1 INTRODUCTION

The Dutch Directorate General for Public Works and Water Management is responsible for the management of the national road infrastructure in the Netherlands. Maintenance is one of the core tasks of this directorate. In the past, maintenance was merely regarded from a technical point of view rather than a user point of view. This situation has changed significantly during the past decade. The user benefits of the infrastructure should now be the driving force for all management activities, including maintenance.

As a result of this development, bridge management is no longer the exclusive territory of a limited number of experts within a local maintenance staff. An explicit justification of the maintenance need is required consisting of functional justification; what is needed and how do the road users benefit, and what is the financial justification and what is the cost involved. To fulfil these demands the key features of bridge management are knowledge of the asset represented in meaningful data, a clear strategy for maintenance, a prognosis of future maintenance cost and last but not least a management process that integrates these features.
The development can be characterised as follows. Maintenance management used to be a sort of craft, experience based, highly depending on implicit, qualitative local knowledge. The development we foresee, moves towards a more scientific approach, based on explicit, quantitative general knowledge. The progress made in the "learning" process that comes with the transformation from craft into science is described in the following sections.

2 THE ROAD NETWORK

The Dutch national main road network consists of 3200 km of road, including 2200 km of motorway. It serves mainly one function, accessibility, while traffic safety and environmental aspects are also taken into account. The maintenance management of the network divides assets into four object categories: pavements, structures, traffic facilities and environmental assets. The total number of structures in the network is 3929. The structures are categorised into generic types, each having its own maintenance characteristic. An overview of the types, their number, deck area and replacement value is given in Table 1

Object	Number	Deck area [m^2]	Replacement value [M Euro]
Concrete bridge	3714	6157646	6 400
Steel bridge (fixed)	125	410264	600
Movable bridge	69	56347	1 100
Tunnel	14	259935	1 600
Aqueduct	7	21452	300
Total	3929	6905644	10 000

Table 1 : Replacement value structures

The replacement value of the entire stock of structures is plotted against the year of construction in Figure 1. This figure shows a peak in construction activities in the seventies. Such a peak is characteristic for many Western European Road networks.

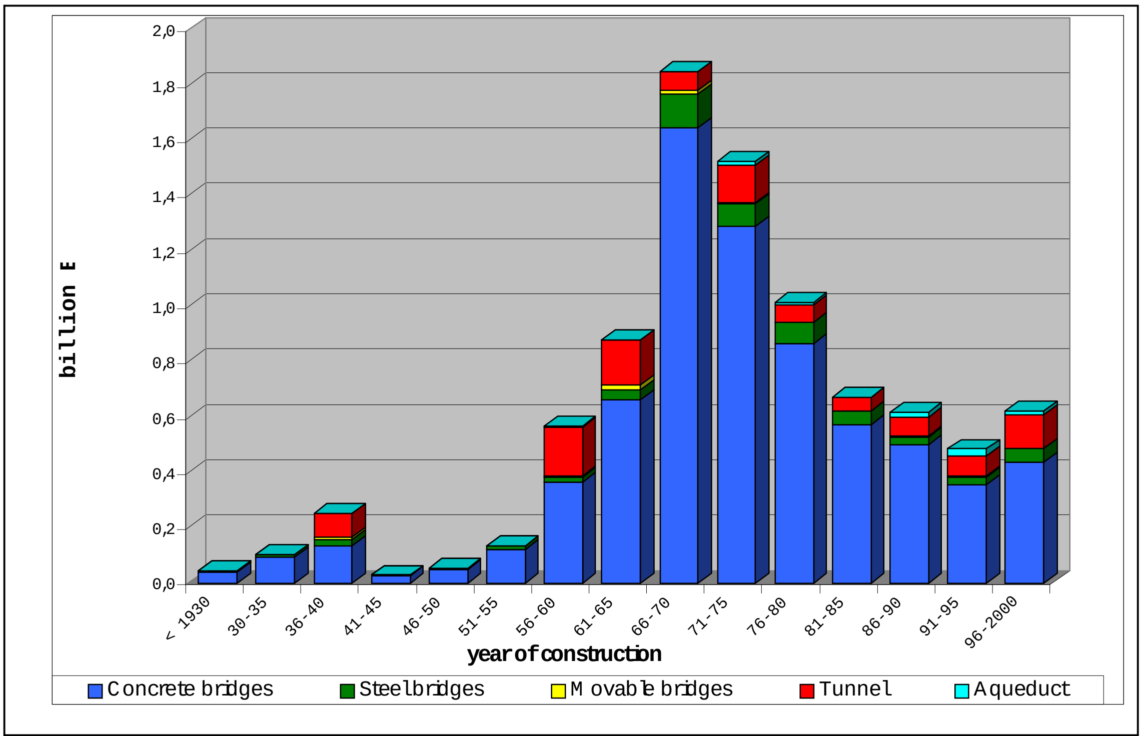

Figure 1: replacement value related to year of construction

3 METHODOLOGY

The maintenance methodology used in the Netherlands distinguishes three hierarchical system levels: networks (e.g. a highway network), structures (e.g., a bridge) and components (e.g., a joint). The maintenance need should first be justified by the functional requirements related to policy goals applied to the network. These goals are rather abstract and have to be specified from a network level to requirements on a structural level. At this level there are two possibilities. Either the structure fulfils all requirements and preventive maintenance can be applied or the structure does not comply to all demands and adaptation or replacement will be necessary. This second option is defined as “essential maintenance” in the BRIME report[1]. In the Netherlands replacement of structures is treated in a programme separate to the maintenance programmes. There can be various reasons to replace a structure, such as the end of the technical life. A study into lifetime distributions of bridges in the Netherlands is reported by van Noortwijk and Klatter[2].

A maintenance strategy is drawn up at component level for frequently used components. Such a strategy requires of a description of the minimal acceptable quality or condition, or a description of acceptable defects. Once the strategies are outlined, they can be applied to the stock of structures in operational practice, and used to estimate the total maintenance cost.

This cost is related to the policy goals. When this relation is qualitatively described, it will form the basis for budget planning and prioritisation of the maintenance programmes.

4 MAINTENANCE STRATEGIES

A specific maintenance strategy is set up for component types. In most situations, a maintenance strategy based on the inspection of a structure's condition is most appropriate. This is known as condition based maintenance. The next step is a prognosis of the maintenance cost based on cost indicators and maintenance intervals for standardised measures. A correct estimate of the maintenance intervals and the cost of standardised measures is an essential, but difficult part of the methodology. Three phases of this process can be distinguished; to start with figures based on expert judgement, then make a complete cost calculation for the standardised measures combined with an evaluation of registered data of maintenance intervals, and finally the use of deterioration models and data of physical parameters to predict the maintenance cost. The learning cycle of forecast, comparison with experience and evaluation resulting in a more accurate prediction has to be established. In the Netherlands we are currently in the second phase of this process. The maintenance strategies, including standardised budget items are described in so-called Reference Documents, which are drawn up for groups of similar components eg. concrete components, preserved steel, extension joints, and bearings. As an example some figures for frequently used components are presented in Table 2.

Component	Measure	Unit	Unit cost [EUR]	Interval [year]
Bridge deck including pavement	Replacement wearing course	m^2	11	12
	Replacement pavement and concrete repair	m^2	38	24
Joints	Maintenance	m	340	12
	Reconstruction	m	1360	24
Concrete structure	Concrete repair	m^2	10	30

Table 2: Example of standardized measures

Note the unit cost is related to the entire component size. The unit price for concrete renovation is rather low, because only 1% of the entire area is expected to be repaired.

5 MAINTENANCE COST FOR GROUPS OF STRUCTURES

For each structure, maintenance cost is estimated on the basis of the Reference Documents. Afterwards, these results are compared with the inspected state and, if necessary, adapted to the actual situation. After aggregation over the entire stock and prioritisation of available budgets, this process leads eventually to operational maintenance programmes[3,4]. The prognosis of the maintenance cost for components of structures can be applied to the groups of structures. A typical maintenance plan for a concrete highway bridge is given in Table 3.

Note that this plan is based on statistical data. The execution plan has to be optimised by results of inspections and grouping of measures.

		Maintenance cost per 5 year interval [K Euro] Age (year)													
Component	Size	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70
Deck	1000 m^2			11		38			11		38		11		
Joint	60 m			20		82			20		82		20		
Concrete	1500 m^2						16						16		
Edge beam	100 m						2						2		
Bearing	18 unit						23						23		
Guard rail	100 m				9				9				9		
Railing	100 m				5				5				16		
Routine maintenance		3	3	3	3	3	3	3	3	3	3	3	3	3	3
Inspections		2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total cost interval		5	5	36	19	125	46	5	50	5	125	5	102	5	5
Total annual cost		1	1	7.2	3.8	25	9.2	1	10	1	25	1	20	1	1

Average annual cost 7.7 Euro / m^2 deck

Table 3: Maintenance cost of a typical concrete highway bridge

The prognosis of the maintenance cost for components of structures can be applied to the entire stock of structures. This results in the maintenance cost on a network level. A similar approach is reported by Das[3]. Table 4 gives the total annual cost per structure type.

Type structure	Total annual maintenance cost [M Euro]
Concrete bridge	43.4
Steel bridge (fixed)	33.1
Movable bridge	4.5
Tunnel	11.9
Aqueduct	0.6
Total	93.5

Table 4: Annual maintenance cost of each type of structures

These costs are coupled to the policy goals by the maintenance strategies drawn up per component. This relation has to be expressed in a language that facilitates the communication between technicians and management. For this purpose a report has been developed that describes the relation between maintenance cost and the policy goals. This report has a format similar for the other object categories of the network, such as pavements.

6 SERVICE LEVELS FOR MAINTENANCE

The development of infrastructure management from a purely technically oriented approach towards an approach, where user benefits form the driving force, moves through a number of stages. It starts with a growing awareness for user benefits, leading to a definition of functional requirements in addition to the existing technical requirements. The next phase is to define service levels, first in a qualitative way, to be followed by quantitative service levels and performance indicators. The approach has been parallel to the defining of the maintenance programmes and budgets. A final step would be to focus on user cost and maintenance cost integrated in a life cycle cost approach. The development in the Netherlands is now at the stage of defining qualitative service levels.

Maintenance in general is aimed to sustain the function of the infrastructure. From the point of view of the road users, maintenance should contribute to the quality of the road. The user has a common sense feeling that an increase of maintenance improves the quality of the road, while a decrease of maintenance reduces this quality. There must be a point where the price of maintenance is justified by the required quality of the road. This common sense principle is taken as a starting point to define the quality in terms of a service level. Such a service level consists of five types of policy objectives; accessibility, traffic safety, environmental quality, comfort and aesthetics. A brief explanation of these five policy objectives is given below.

- Accessibility relates to the primary function of the structure for traffic. Quantitatively this implies availability. A structure can be not available during maintenance activities or due to failure of installations. The quality of the structure directly related to the traffic is also included in this objective. Aspects are structural reliability, load carrying capacity, user safety (not directly related to traffic safety) and durability.
- Traffic safety comprises user safety directly related to traffic actions. The condition of the road surface and the guard rail are the most relevant components for this.
- The environmental quality in the definition used is determined by the noise production of the traffic using the structure. The condition of the road surface, pavement and joints, is the dominant factor.
- Comfort is used to express an extra user quality. This aspect is also determined by the quality of the road surface.
- Aesthetics are determined by the external design of the structure. The most relevant items for maintenance are the color and the shape of the visible surface.

The quality required is expressed in terms of these five objectives. In these terms a basic quality can be defined. The effect of variation in maintenance efforts can also be described in the same terms. A relation can now be established between quality and cost. This relation enables a defined discussion between management and technical staff resulting in agreed maintenance budgets and quality. The components of the structures are used as links between functional and technical requirements and maintenance cost. The functional justification as well as the financial justification of these links are given by the Reference Documents described in the previous section. For a type of structure representing a group in the network, the relations are described in the table below (in this case for concrete bridges). This corresponds to the structure maintenance plan for the group in Table 3.

Concrete bridges	Accessibility	Traffic safety	Environmental quality	Comfort	Aesthetics	% of total cost
Bridge deck including pavement	++	+	+	+	--	18%
Joints	++	+	+	+	--	43%
Concrete structure	++	--	--	--	0	7%
Bearings	++	--	--	--	--	8%
Guard rail	0	++	--	--	0	5%
Railing	++	--	--	--	0	5%
Routine maintenance / inspections	++	+	--	--	0	14%
					Total	100%

Importance of policy objectives for maintenance:

++ dominant
+ important
0 neutral
- not important
-- not relevant

Table 5: Maintenance need related to policy objectives

7 PRIORITISATION

The effects on policy objectives can be used in prioritisation of the maintenance programs. Prioritisation will be necessary when the maintenance programmes that are drawn up do not fit into the available budgets. The effect of adaptation of the programme can be described in terms of policy objectives.

	accessibility	traffic safety	environmental quality	comfort	aesthetics	reduction of maintenance cost [M Euro]
concrete bridges: concrete maintenance -10%	-	0	0	0	-	0.14
steel bridges: preservation steel -10%	-	0	0	0	-	1.8
pavement maintenance: loss of material wearing course +20%	-	-	-	-	-	14

0 no influence, - negative effect, -- major negative effect.

Table 6: Effects of prioritisation

A similar approach has been applied to pavements and traffic facilities. This way a comparable assessment of the maintenance cost on the network level can be made. To give an example three different options for the reduction of maintenance cost are presented in Table 6; Reduction of concrete maintenance by 10 %, Reduction of steel preservation by 10 % and less strict criteria for loss of material from the wearing course in pavement management. The effects are scored against the five policy objectives and presented together with the cost reduction. The results will not be discussed in detail. They are only intended as an illustration of the methodology. The effect ratings are taken from a real case.

The effect on the cost reduction of structures seems small compared to the pavement case. The aspects directly related to the road users dominate. It should be noted that reduction of maintenance reduces the lifetime of the structures. This effect was not fully accounted for. Further development is needed, but he start of the discussion looks promising.

8 CONCLUSIONS

Maintenance strategies based at component level can be applied to the stock of structures to estimate maintenance cost on a network level. This prognosis can be updated with inspection results to derive operational maintenance programmes. Evaluation of the operational programmes and the network prognosis forms a powerful learning cycle.

The justification of the maintenance programmes can be expressed in terms of policy effects on user related objectives. This qualitative description forms the basis towards quantitative performance indicators. The same policy objectives can be applied to other object categories, such as pavements. This enables prioritisation on a network level.

Further development is needed on quantitative performance indicators related to user cost and benefits, prediction of deterioration processes of structure components and effects on performance and integration of these into a life cycle approach.

REFERENCES

[1] R.D. Woodward (Project coordinator), “Bridge Management in Europe”, TRL United Kingdom, contract nr: RO-97-SC.2220, (2001).

[2] J.M. van Noortwijk, and H.E. Klatter, “The Use of Lifetime Distributions in Bridge Replacement Modelling”, First International Conference on Bridge Maintenance, Safety and Management, Barcelona, (2002).

[3] Ministry of Transport and Public Works, “Workshop Optimal Maintenance of Structures”, Delft, the Netherlands, ISBN 9036933072, (2000).

[4] J.D. Bakker, “Translating Survey Results into Management Data”, 9th International Conference on Structural Faults and Repair, London, United Kingdom, (2001).