THE ZAANSTAD-VIAVIEW PAVEMENT MANAGEMENT SYSTEM FOR BLOCK PAVEMENTS

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SUMMARY

The municipality of Zaanstad is situated on a subsoil of low bearing capacity and high subsidence. Consequently, subgrade settlement is generally more important for pavement deterioration than traffic loading, and existing pavement deterioration models are not applicable.
Therefore, a "taylor-made" management system for block pavements was developed, based on a visual condition survey of three relevant damage types: longitudinal profile, height level and surface drainage.
Based on 9 years of quality ratings for 700 roads, deterioration models have been established, that describe the development of damage in time.
The parameters for these models have been curve-fitted for 14 combinations of road category and traffic loading, thus taking into account all local conditions, including type of structure and soil stability.
Based on experience, safety considerations and political choices, minimum quality requirements acceptance levels have been established too.
The visual condition data, performance models and condition criteria, together with "inventory" data (location area, age, pavement type, etc.) have been entered into the Viaview computer program. This has many easy-to-use data retrieval options, to answer any question about the pavements.
It also enables to calculate a maintenance plan and the budgets required, given minimum quality requirements; or calculate a maintenace plan with the economic optimum time and type of maintenance and the resulting quality levels, given the available budgets.

1. INTRODUCTION

The municipality of Zaanstad is situated in the western part of the Netherlands, close to Amsterdam (see figure 1), on one of the worst subsoils, consisting mainly of peat. It is located in a polder about 1.5 m below sea level.
In 1969, Zaanstad was formed from the municipality of Zaandam and six surrounding municipalities. Before that time the pavement management system was based on the "know your city"-principle, meaning that the priorities were determined by the town-council. As from 1969 in Zaanstad a visual condition survey system was set up; using predefined criteria for the quality of the pavements a reduction of quality in time could be observed. In 1988 the question arose whether based on these visual condition data it might be possible to predict the future behaviour of the pavement condition. Netherlands Pavement Consultants was invited to carry out a study in order to develop block pavement performance models based on the Zaanstad data and incorporate them in their VIAVIEW pavement management computer programme.
The present system is based on four pillars:

- inventory data of the road network (names, location, classification, pavement type, length, area, etc.)
- visual condition data (damage types and ratings)
- performance models (relationships between pavement quality and time)
- knowledge and experience of pavement management officials and consultants

In this paper the evolution of the Zaanstad Pavement Management System (P.M.S.) is described as well as the nowadays existing and operational system.
As the inventory data are not specific to the Zaanstad Pavement Management System, they will not be discussed further. The other items will be detailed below.

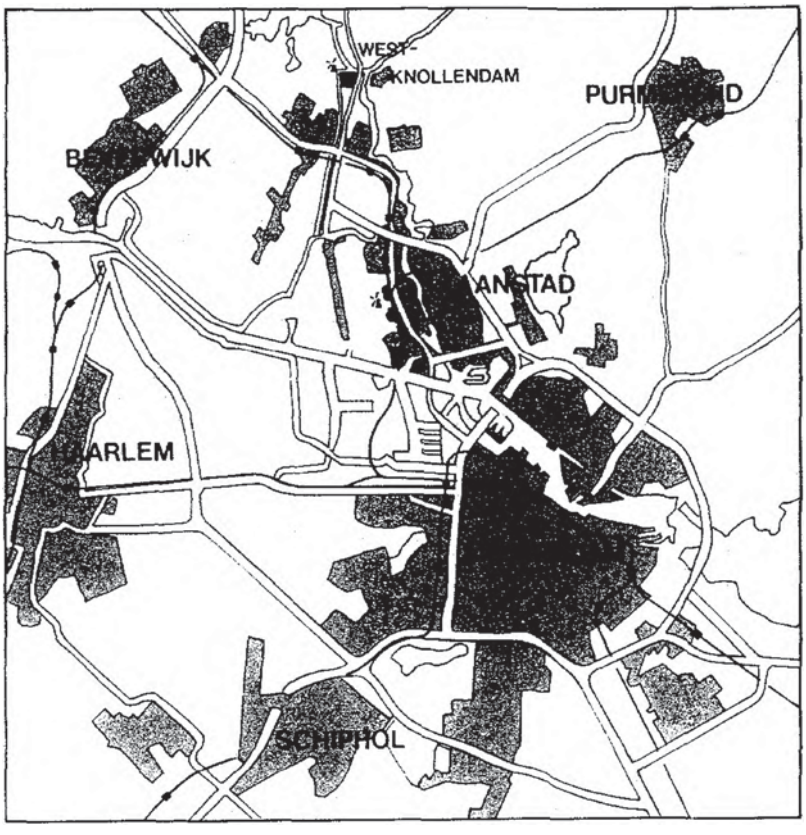


Figure 1: Zaanstad within The Netherlands.

Before discussing the existing pavement management system, it is necessary to describe its underlying philosophy, because that defines the boundaries of its applicability and use.
It must be stated that visual condition survey data alone are often hardly sufficient to establish the cause of the damage and hence the correct maintenance treatment. This holds especially true, when the visual condition data are compressed into ratings.
E.g. when the longitudinal profile is badly undulating, this may be caused by local depressions, uneven settlements, sewerage works, tree roots, or any other of a number of possible causes. In some of these cases a visual condition surveyor may be able to establish the right cause (but this information gets lost when he summarizes his survey into a quality rating), in other cases further investigation is necessary.

Furthermore, a computer program cannot take into account additional factors of which it has no knowledge, such as construction data, (expected) changes in traffic, coordination with sewer or cable maintenance, exceptional damage, ground water influence, etc.
Of course it would be possible to incorporate all these factors into a pavement management system. That would make it very bulky and inefficient however, because of the need to gather and administrate a lot of detailed data on roads without present need of maintenance.

Therefore a two-step approach is adopted, in which the computerized pavement management system performs the global planning on network level (all roads together) and the pavement manager performs the detailed planning on project level (few roads or road sections at a time).

In this approach, the pavement management system:

- is based on a restricted number of relevant data,
- is therefore relatively cheap to fill with data,
- is transparent and easy-to-use,
- gives possibilities to explore available data,
- enables to signal urgent maintenance needs,
- estimates required budgets,
- shows the consequences of inadequate budgets,
- focuses the attention of the pavement managers on those sections in need of maintenance,
- but leaves the complicated final decisions to the pavement manager.

Thus the pavement management computer program serves as a tool for the pavement manager, not as his replacement.

2. THE ZAANSTAD PAVEMENT MANAGEMENT SYSTEM

2.1. The Zaanstad visual condition survey

During the years 1978 till 1990 the Zaanstad visual condition survey has developed into a system that uniformly describes both type and amount of distress. The system discerns three damage types which the evolution of the system has shown to be the most significant for Zaanstad:

- longitudinal profile
- height level
- drainage over surface.

Because of the rather weak subgrade in the Zaanstad area (peat and clay), the settlement of the subgrade with its consequential disturbance of the road construction, is generally more important than the influence of traffic (especially when heavy traffic is mostly absent). This is reflected in the damage types considered.
The longitudinal profile is important for traffic comfort and safety and bears some impact on drainage.
The height level of the road surface (which can fall some 150 mm in 5 - 10 years in some cases) is important because of its relation to the sewer inlets, manholes, and surrounding buildings (generally not subject to settlement because of pile foundations).
Furthermore, when a road sinks into the influence zone of the ground water also its structural stability is threatened.
Drainage may be related to height level and longitudinal profile but also to traffic loading (rutting) or sewer condition (blockage of sewers or sewer inlets). It is important because of traffic comfort and safety, but also because of structural stability. The latter holds especially true in the case of block pavements, where undrained surface water will easily penetrate into the pavement structure and cause serious deterioration.

All damage types are visually surveyed by trained and experienced inspectors and rated from 0 to 100 (with increments of 5). These ratings may be thought of as percentages of quality, where 100 means a perfect quality and 0 means a disastrous condition. Objective guidelines exist to transform measurable damage into a quality rating, but these are not entirely "water tight", leaving some room for a subjective interpretation of the inspectors. Because of the extensive training and experience of the inspectors however, the ratings of different inspectors for the same road are remarkably stable.
Furthermore, when possible, the survey of a road is done in the same month each year, to eliminate seasonal influences.

In table 1 the matrix is given that is used by the surveyor to determine the rating. (It should be noted that the descriptions in the boxes of the matrix are not complete. This table only serves to show the types of distress surveyed).

	Height level		Drainage	Profile						
Quality	Rating	Loss of height(cm)	Rating	Rating	Surface	Shape	Longitu-dional	Trans-versal	Sides	Space between blocks
good	90		90	90						
	80		70	70						
reasonable	80		70	65						
	75		60	55						
moderate	70		55	55						
	70		50	50						
bad	70		50	45						
	65		45	40						
very bad	65		40	35						
	50		30	30						

Table 1: Quality-damage type matrix.

In the boxes of the matrix exact objective descriptions of the different items are given.
Those descriptions are discriminating to be able to put the quality of the pavement in the proper rating.

It should be noted that in the rating of the different types of distress a kind of weighing factor is built in; a quality called reasonable has a lower limit of 75 for height level and 60 and 55 respectively for drainage and profile, meaning that height level has a lower impact on the final rating (the sum of the three ratings) than the others.

2.2. Development of performance models

Pavement performance models are often based on fatigue relationships, implying that the quality of the pavement (its ability to bear traffic loadings and to resist damage) remains nearly constant for a long time until the fatigue limits are reached, after which a rapidly increasing deterioration occurs. Graphically this is represented in figure 2.

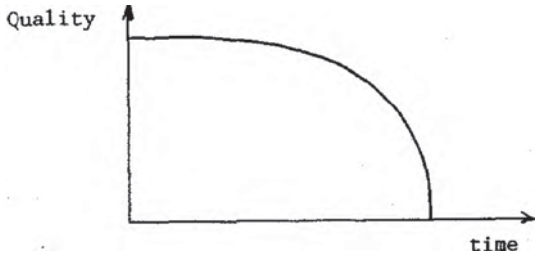


Figure 2: Pavement performance model based on fatigue

In the case of Zaanstad roads however, pavement performance is mainly influenced by geological processes which have an opposite behaviour, implying that the first damage is the worst and that the deterioration rates decrease with time, as shown in figure 3. (At the very end of the pavement life, an increasing deterioration occurs, however, mostly because of combined moisture and traffic damage. This is shown as the dotted line in figure 3. For the serviceable part of the pavement life this is not relevant.)

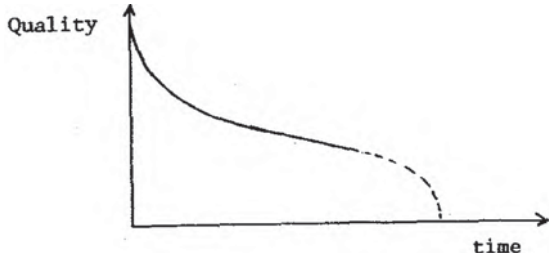


Figure 3: Pavement performance model based on settlements.

For a large number of Zaanstad roads (700) an analysis has been made of the quality over a period of 9 years (1980 - 1988). In this analysis, damage is defined as the complement of quality, thus:

damage - maximum quality rating minus actual quality rating (1)

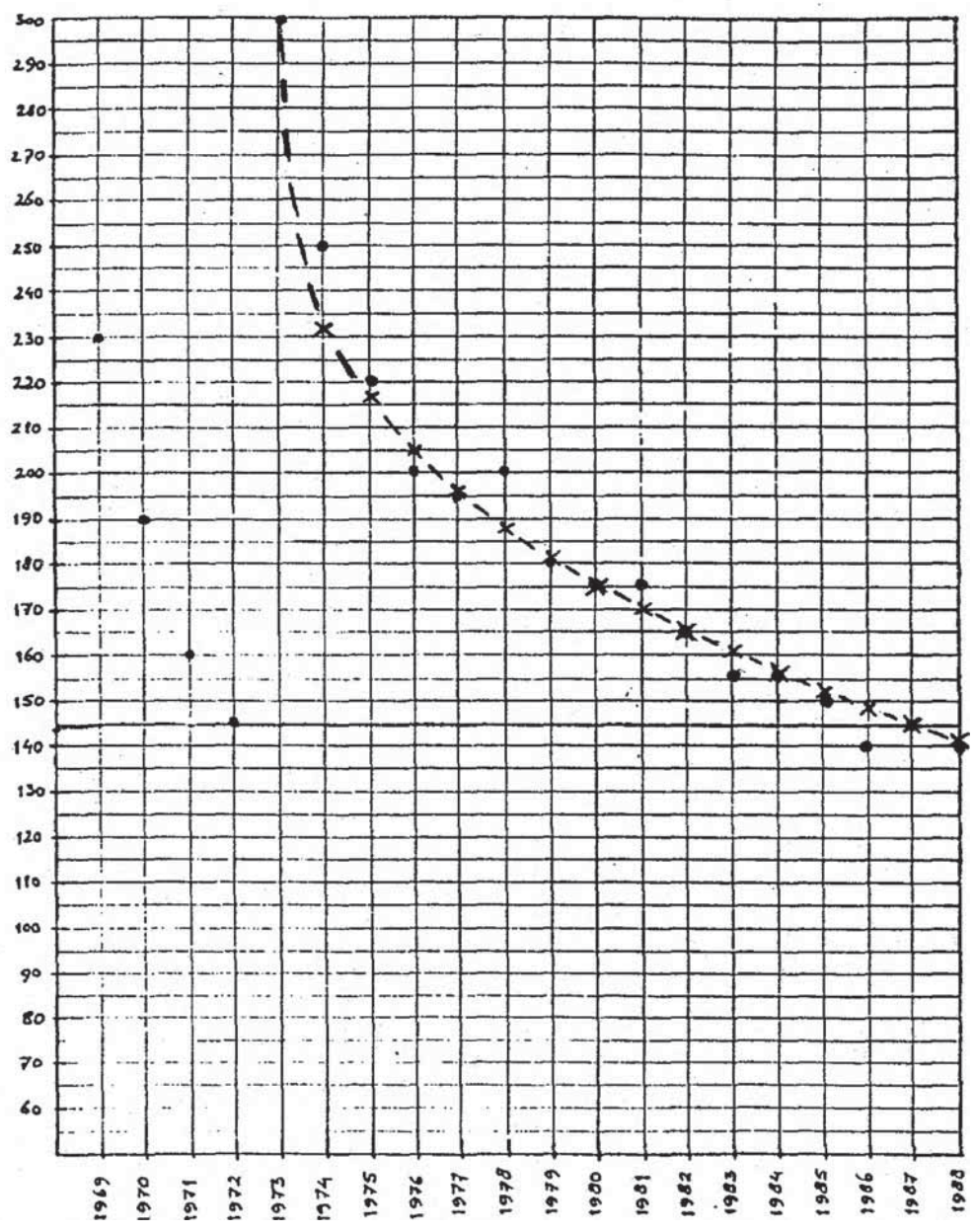
So, e.g. when a road section has a drainage quality rating of 75, the damage rating is 100 - 75 - 25.
It was found that the development of the damage in time could be well described with a power relationship of the type:

$$\text{damage} = A * (t/T)^3 \quad (2)$$

where t = age of construction
T = life of construction
A, B = parameters

The parameters A and B have been established by curve fitting this relationship to the survey data of Zaanstad. In this way, local influences like soil stability and traffic loading are automatically taken into account in the performance models. An example of the curve-fitting is shown in figure 4.

Municipality : Zaandam section : 9
Street : Bijlstraat



- Condition rating by visual inspection

X Calculated quality level, using the performance model

Figure 4: Example of the curve-fitting of the visual condition ratings.

It was found that the values of A and B had a correlation with the type of road, so a distinction into 14 road- and traffic-categories was made. Those categories are given in table 2.

Primary distributor
Primary distributor + bus route
Primary distributor + bus & industrial route
Secondary distributor
Secondary distributor + bus route
Secondary distributor + industrial route
Secondary distributor + bus & industrial route
Tertiary distributor
Tertiary distributor + bus route
Tertiary distributor + industrial route
Tertiary distributor + bus & industrial route
Residential road
Residential road + industrial route
Residential road + bus & industrial route

Table 2: Road Categories

Now, when the damage of a road section at a particular time, is determined by visual condition surveys is known, the ratio t*fT* can be calculated by means of equation (2). By subtracting t from T, the residual life of the construction is calculated. The time until maintenance is needed is significantly shorter than the residual life, however. This is shown in figure 5.

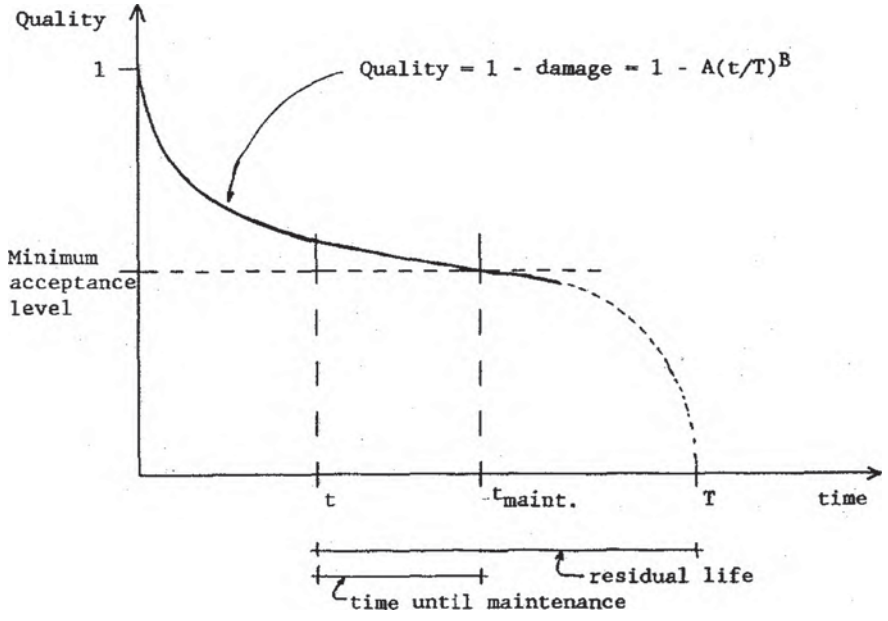


Figure 5: Relationship between time and quality.

Condition level criteria (minimum acceptance levels) have been introduced in the system.
These criteria represent the minimum acceptable level of quality for each road section.
The minimum acceptance level for Zaanstad is established at a quality rating of 145. This is based on both pavement manager's experience and political choices. The experience shows what condition levels are acceptable for safety and what levels are desirable for comfort. The political choices establishes the level of comfort the community is willing to pay for.

2.3. Knowledge and experience

In all pavement management systems the knowledge and experience of local pavement management authorities (when necessary supplemented by those of a consultant) are essential, both in the conception of the system and in its use.
During conception of the system, the local authorities have the background knowledge about pavement structure, function and traffic data which enables to group similar roads together into road categories with a specific performance model.
Also, they mostly have a long experience as to what rehabilitation treatment is best suited to a certain type of damage, age and road category. This experience can be entered into the pavement management system to let it make realistic proposals for maintenance treatments. Also, knowledge of local costs and (politically) required condition levels are important inputs for a pavement management system.
Last, the experience of the local authorities is essential in the validation of the system, because the experience serves as a reference to which the system can be tuned and adjusted.
When the system is tuned and in use, knowledge and experience remain important, both to signal and incorporate new trends (increased traffic loadings; town extension into areas with different soil characteristics, demanding new performance models) and to interprete the results of the pavement management system with sound engineering judgement.
After all, the system is only based on visual condition survey and average performance models and cannot take into account all individual factors and exceptions to the rule, which influence the maintenance decisions for an individual road section.

3. THE VIAVIEW SYSTEM

3.1. Data base

As described before, part of the p.m.s. consists of a large data bank with inventory and visual condition data of all road sections. Figure 6 shows the basic data for a road section.

```
Roadno..:   9000 Name: Abeelstraat                    card     1 of     4 cards
INVENTORY                                  INSPECTION
  Sectionno :      1
  fr. length:      0 m                      Year inspect..:   91
      descr.: Meidoornstraat
     houseno:                                                Meq     visual
  to length:       0 m                                                rating
      descr.:
     houseno: 31                            Long, profile.:   35        65
  Drawing...: 25Bn476/ 25Bn496
  Remark... . :
  District.......:  section 03              Height level..:   20        80
  Roadcategory.,.: estate road
  Function.......:  carriageway
  Pavement.......: concr. block (type2)     Drainage......:   15        85
  Lane...........:  total width
  Mainten. sectno: 4536
  Tdtal length...: Ill m
  Total area.....:    541 m²
  Year construct.:      73
  Year repave....:      87
```

Figure 6: Basic data for a road section.

Of course, this data bank is made readily accessible, so that all available information can be output to answer any questions that might arise, such as:

what is the present condition of street X ?
what is the total area of pavement type Y in districts A, B and C together ?
what is the total length of road sections with insufficient drainage, and where are they located ?
what are the road sections with the worst longitudinal profile ?

In this way it is also possible to obtain a quality ranking of all road sections, which might serve as a maintenance needs urgency list. The p.m.s. has more sophisticated ways to help maintenance planning however.

3.2. Planning

This is the most important part of the VIAVIEW program used in the Zaanstad pavement management system.

Using this part, the quality consequences of different budgets or, vice versa, the budget consequences of different condition criteria can be calculated and thus, the optimum budgets and condition criteria can be found in the following way.

Based on age and visual condition data together with the performance models, the pavement management system is able to predict the residual life of all pavement sections and also the moment when they will fail to meet the condition level criteria.

Considering the type and amount of damage present and the age of the pavement, the program calculates a proposal for a maintenance treatment for each pavement section and the corresponding costs.

Two types of planning are possible with the VIA VIEW program:

condition planning, which proposes a maintenance treatment for each section as soon as that section reaches the condition criterium (minimum acceptance level);
budget planning, which distributes a stated budget over the sections needing treatment, in such a way that the highest cost/benefit ratio is gained and that for each section the optimum point in time for treatment (given the available budget) is calculated.

The condition planning guaranties to keep all road sections above a stated quality or condition level. In doing so however, widely varying yearly costs may result. The budget planning is very useful to make the best of a (politically) given budget, even when it is not high enough to perform the necessary maintenance to keep all pavement sections in a good condition. It will also show the consequences for quality of such a budget. By performing multiple planning with trial budgets, it is possible to calculate the budget constantly needed to keep the pavement network in a certain condition. In this way, a fairly accurate view can be gained of the overall quality of the pavement network and the budgets required for maintenance. Figure 7 shows the given budgets and the corresponding quality level.

The VIA VIEW program will also generate lists of the proposed treatments per section or per year. This serves to focus the pavement managers attention to the most relevant road sections and to aid him in further detailed planning.

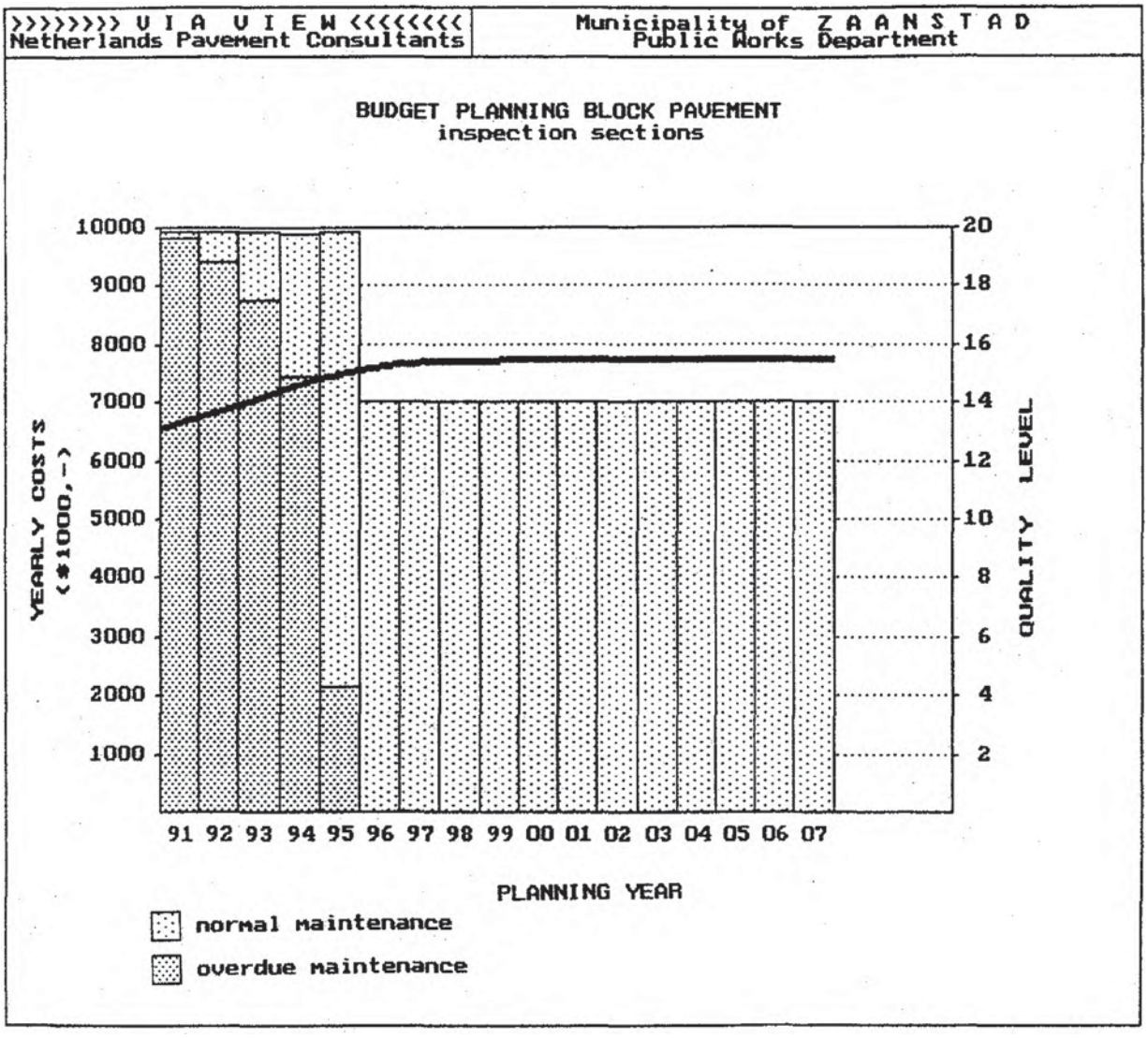


Figure 7: Maintenance budgets and quality level.

3.3. Refinements

When in use, the results of the system are constantly checked against the knowledge and experience of the pavement manager and consequently refined and adjusted.

Some examples of validations and adjustments:

town extension into a new area with very weak soil conditions demands for new performance models which describe the deterioration of the new road sections. At first, these new models are extrapolated from existing situations, later they are adjusted as the predicted behaviour can be checked against the actual behaviour;

at first, one condition level criterium was used for all road categories. Later this was differentiated, due to local streets in living areas, because of lower traffic velocities, can tolerate more unevenness than primary or secondary distributor roads;

when the actual behaviour of a number of roads does not match the model of the road category into which they are grouped, these roads can be transformed into another road category or even into a new category. The latter must not be overdone of course, because an abundance of road categories (although technically possible in the program) may result.

4. CONCLUSIONS AND RECOMMENDATIONS

In this paper the ZAANSTAD Pavement Management System for block pavements has been described. This system is based on visual condition surveys and the VIAVIEW computerprogram. Once again it is stated that when a computer based pavement management system is used, the experience of local authorities will always be required to tune the system. It is shown that a pavement management system can be fit to purpose when incorporating both an excellent computer program and the knowledge of highly experienced local officials and consultants. Performance models, developed from inspection data for specific conditions can be easily fit into the computer program to serve local circumstances. The division of road categories based on the amount of traffic has proven to be a proper one.

The great advantage of the VIAVIEW computerprogram, that is being able to calculate budgets and condition levels for many maintenance scenario's very fast, is fully explored in the Zaanstad Pavement Management System.

It can be concluded that because of integration of knowledge and experience of both Zaanstad and Netherlands Pavement Consultants a tailor made Zaanstad Pavement Management System has been developed that will help spending the available budgets in the most optimal way.