

# **Bridge Management—Routine Maintenance: Recent Experience with the Routine Management Module in the DANBRO Bridge Management System**

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## **ABSTRACT**

The bridge stock in Denmark consists of thousands of bridges ranging from very small to spans of about 400 m. All these structures are maintained systematically by using the Bridge Management System DANBRO. This paper shows by examples how preventive maintenance (PM) is managed with DANBRO.

PM or routine maintenance is essential for economic management of bridges. Most PM activities are implemented during routine inspection and extended routine inspection. Some bridge owners do not use PM, but they pay much more for bridge maintenance in the long run.

Previously, PM was carried out using the DANBRO Management System. The bridge owners' own staff carried out maintenance periodically, mainly. In the 1990s, authorities were compelled to use private contractors for many of these activities. Consequently we had to change our management routines, work routines and computer systems. The following documents had to be revised:

- Contractual and payment specifications
- General work specifications
- Special work specifications
- Bill of Quantities
- Checking procedures

At first it was difficult to operate under new conditions, but the changes now seem beneficial for all parties.

## **INTRODUCTION**

This article is intended for those who administer, operate and maintain bridges or other types of structures. The object is to introduce the reader to some of the possibilities of the EDP-based bridge management system DANBRO for facilitating the administration, operation and maintenance of a large and varied stock of structures.

## **ROUTINE MAINTENANCE**

This consists of minor repairs that are frequently needed and can be carried out with the aid of simple tools on the basis of standard instructions (e.g., minor repairs on concrete, patches of paintwork, replacement of bitumen joints, sweeping and hosing).

It also includes remedial measures in connection with aging or wear caused by climate or traffic.

Some of the maintenance is carried out at irregular intervals, usually after a report has been received—e.g., on impact damage or erosion damage after unusual weather.

Many bridge owners simply forget these activities, and there are many examples of major repairs (involving road-user costs) that could have been avoided if minor maintenance work had been carried out in time.

Another cause of inadequate maintenance is that the bridge owner is not clear about who is responsible for maintaining what. Is it the owner of the intersecting passage? Is it the watercourse authority? Is it the railway authority? Is it a private person?

It can also be the result of “departmental thinking”; if one authority is responsible for routine maintenance and another for the bridge itself, the result can be inadequate maintenance.

Other types of work are covered by routine maintenance (mentioned below), but in general it consists of work that is not too complicated and is not priority-ranked via special inspection, i.e., works that cost less than 30,000–100,000 DKK, depending on the bridge owner.

Carrying out systematic and intensive maintenance can make considerable savings, and for owners that have already adopted this maintenance system it has resulted in a substantial extension of the service life of many structural components and bridges.

## **ROUTINE MAINTENANCE WITH DANBRO**

### **The Aim**

The aim of maintenance is to maintain the required level of traffic safety at all times, and to compensate for the effects of weather and traffic on the structures so that serious and costly damage is avoided.

Maintenance work can be carried out by the management’s personnel or can be put out to tender.

The objects of using DANBRO as a management tool today are to ensure

- that no maintenance works on bridges or their components are forgotten
- that the contractor for each bridge can obtain a detailed and complete overview of the works to be carried out, and thus achieve optimum management of the works
- that budgets for the total maintenance work can be prepared
- that acquisition of materials can be optimized.

### **DANBRO as a Management Tool**

From 1987 to 1997 DANBRO was mainly used to plan routine maintenance and to keep a check on the materials used, but in the past two years it has been developed and used

for the management of works, contracts and budgets at national, county and municipal levels. These developments are shown schematically below.

1987–1997

Inspection planning  
Materials  
Gross quantities

1997 →

Inspection planning  
Budget management  
Preparation of work orders  
Materials overview  
Gross quantities  
Net quantities  
Quantities used  
Quality assurance

Although the total costs of bridge maintenance vary greatly, the cost of routine maintenance is one of the few expenditures on which the Road Directorate does not economize, and on which no bridge owner should economize, as it is an investment that gives a high return.

### **Important Activities/Modules**

Two important modules that DANBRO's database offers are:

- An overview of the agreements and obligations connected with each bridge (information from the registration module).
- Information on prices for checking the contractor's prices (information from the price-book module), and preparing a provisional budget for the client.

### **Work Process**

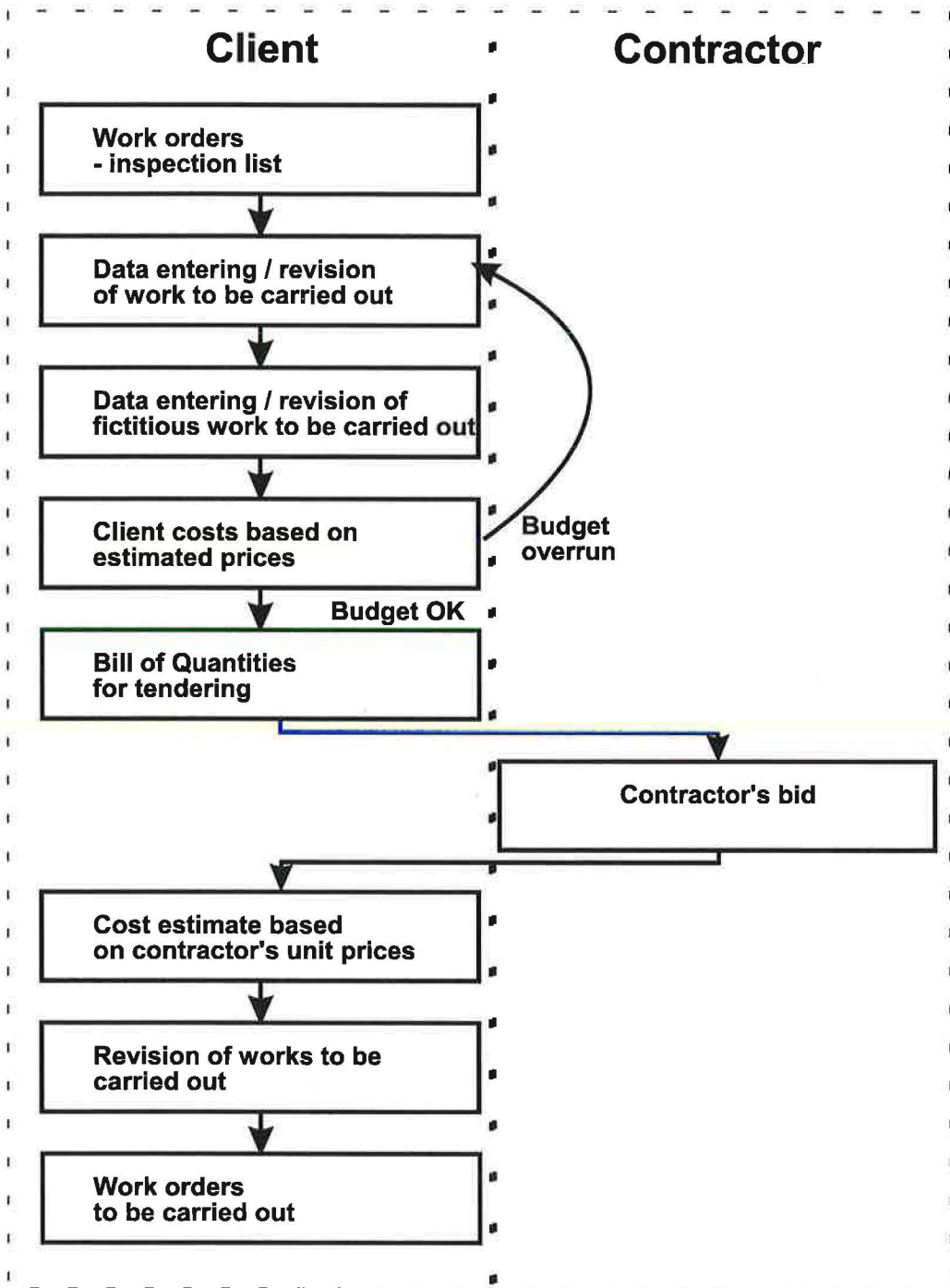
The diagram below illustrates the work process, starting with the result of a bridge inspection reported in DANBRO's database and ending with the issuing of work orders.

## **TENDERING AND OPERATIONAL REGULATIONS FOR ROUTINE MAINTENANCE**

In order to use electronic data processing in connection with routine maintenance, it is necessary to standardize procedures and documents.

### **Tender Documents**

The documents are issued on paper, on diskette and as files on the Internet. It is vital for the implementation of the system that many use the same basis material for tenders.



The following are some of the advantages thereby obtained:

- The client can compare bids.
- The client can compare the maintenance condition of the structures.
- The contractor bids on practically the same basis for the various clients.
- The work is carried out to meet standard requirements, known to client, consultant and contractor.

Regardless of whether an external consultant or the client's own staff is involved, the "skeleton" and basis material is uniform.

### **Developments Since 1987**

The main changes that routine maintenance involves are that the tendered work is often spread over several years, that each work must be carried out in a specified year, and that the works to be carried out in a given year are priority-ranked at the start of the year.

Furthermore, as mentioned above, there are "standard conditions" concerning guarantees, insurances, the execution of the work, the client's payment obligations, time-limit extensions, delays, etc.

#### 1987–1997

No tender  
Work in connection with ad hoc inspection  
Poor documentation of work executed  
No external contractors

#### 1997–1999

Tender covering several years  
90% of the work ordered at the start of the year  
Check on the budget  
Possibility of priority-ranking  
Possibility of work planning

### **General Work Specification (AAB)**

The General Work Specification (AAB) is the document in which the principal types of work are described. The general requirements for each type of work are stated; it is also indicated where more detailed specifications are required for a specific enterprise.

Examples of standard works that can be involved in an enterprise:

- Sweeping
- Grass cutting
- Hosing
- Cleaning
- High-pressure hosing
- Replacement
- Filling
- Patch-painting of steel
- Surface treatment of steel
- Surface treatment of concrete
- Surface treatment of wood
- Removal of unwanted vegetation

- Crack sealing
- Establishing embankment protection
- Establishing drainage manholes
- Establishing drainage channels
- Establishing kerbstones
- Establishing sheet piling
- Establishing fascine protection
- Concrete repairs
- Removal of graffiti
- Surface treatment of asphalt
- Straightening
- Re-establishing
- Tightening of bolts
- Lapping
- Other works

For each work, the following is in AAB: General regulations for work, materials, execution, checking and documentation. The work "Establishing wood piling" (e.g., at a watercourse) is given below as an example of an AAB description:

### **Example**

#### *General*

The work includes driving wooden piles at bridge corners, to prevent erosion, etc.

The site supervisor prepares the required drawing/sketch indicating position and form.

#### *Materials*

Stainless steel and pressure-impregnated wood shall be used.

#### *Execution*

Before purchasing planks the contractor shall test-drive 2 or 3 planks in the presence of the supervisor, so that the necessary length of the planks can be determined.

The planks shall be full-squared, tongue-and-grooved and cut diagonally at the lower end, so that a tight wall is obtained after the completion of driving.

The piles shall be anchored with OE12 mm screw-threaded rods to buried 800 × 625 × 100 mm concrete slabs at 2.0 m intervals.

The piles shall be cut off at approx. 200 mm above the future terrain level behind the piles.

The piles shall be provided with 2" × 5" girts on both sides. The girts are fastened with OE12 mm hot-galvanized bolts at 0.5 m intervals. 50 × 50 mm washers shall be used. After the girts have been fixed, the tops of the planks are treated with insulation No. 0, and a 2" × 5" coping plank is laid and fixed with nails.

In the corner between the piles and the end-wall/wing a 0.5 m wide geotextile is placed, extending from the top of the piles to the base of the drainage channel.

Finally, aggregate fill is placed behind the piling.

### *Supervision*

The column foreman shall check that the work has been carried out according to the specification and any instructions of the site supervisor.

## **Documentation**

Documentation consists in the registration of checking and other data that the client requires to be documented in the tender plan and in other tender material.

In addition, work orders, the extent of traffic regulation measures, relations to pipes and cables and special relations to owners of fish farms, railway authorities, etc. are described.

## **Special Work Specification (SAB)**

Of course, the General Work Specification (AAB) is not always sufficient, but it can be supplemented and corrected. This is the purpose of the Special Work Specification (SAB), drawn up for a specific structure.

It is important that not too many work orders be issued, as this could make the system too complicated. Experience has shown that it is best to specify the type of work on the order, and give a detailed description of it in the Specification.

A DANBRO list of materials is printed out; some of them are already approved, the site supervisor shall approve others.

In DANBRO a bridge or similar structure is divided into 15 principal components and a number of sub-components; if DANBRO is used for other types of structures, the number of components can be adjusted to meet the requirements. Each work is connected to one or more of these components, and the tender documents include an overview of the connections between components and the various works for the enterprise in question.

Contractually, works are of two types: Works priced in the Bill of Quantities and works to be paid on account, i.e., on the basis of the materials, labor, etc. used.

## **List of Materials**

The list contains an overview of many products; “J” indicates that a product is already approved on the basis of the Road Regulations for concrete bridges and the conditions in the tender material.

The list helps the client and the contractor in the choice of materials; the contractor can normally use any listed product, but the client or the site supervisor shall approve “alternatives.”

An extract from the list is shown below:

| DANBRO                           |                              |          |
|----------------------------------|------------------------------|----------|
| Maintenance – Report on products |                              |          |
| Products                         |                              | Approved |
| 1.500                            | High-Build plastic paint     |          |
| 1.501                            | Sika Color – 550 Elastic     |          |
| 1.502                            | Sadolin Pansorflex Thick     | J        |
| 1.503                            | I.D. Flügger Daekso-plast 25 | J        |
| 1.600                            | Antigraffiti                 |          |
| 1.601                            | Kr-antigraffiti              |          |
| 1.700                            | Cleaning agent               |          |
| 9.400                            | Asphalt mastix               |          |
| 9.401                            | Type III                     |          |
| 9.402                            | Icopal, Type 1va             | J        |
| 9.403                            | Phoenix, Type 1va            | J        |

The Road Directorate updates the list, and new products are continually added. It is the intention to make the list as complete as possible, to maximize the client's choices and prevent monopolies arising.

### List of Components and Works

The list gives an overview of the connections between works and components in the enterprise in question. However, the list varies little from enterprise to enterprise.

The list also gives an overview of the units in which the works are measured, and the form in which payments are made. It can be stated whether a work is to be executed as bridge maintenance or road maintenance.

An example of a list of components and works:

| DANBRO               |                                  |                |              |             |
|----------------------|----------------------------------|----------------|--------------|-------------|
| Maintenance – Report |                                  |                |              |             |
| Component and work   |                                  | Unit           | Payment form | Road maint. |
| <b>2.00</b>          | <b>Wings</b>                     |                |              |             |
| 53.06.01             | High-pressure hosing of surfaces | m <sup>2</sup> | T            | N           |
| 53.11.01             | Surface treatment of concrete    | m <sup>2</sup> | T            | N           |
| 53.21.01             | Concrete repairs                 | m <sup>2</sup> | R            | N           |
| 53.22.01             | Removal of graffiti              | m <sup>2</sup> | R            | N           |
| 53.50.01             | Cleaning, shovel and broom       | m <sup>2</sup> | T            | N           |
| 53.51.01             | Diverse works on account         | No.            | R            | N           |
| <b>2.01</b>          | <b>Wings, soft joints</b>        |                |              |             |
| 53.07.01             | Replacement of soft joints       | m              | T            | N           |
| <b>3.00</b>          | <b>Embankments</b>               |                |              |             |
| 53.03.01             | Grass cutting                    | m <sup>2</sup> | T            | Y           |
| 53.08.04             | Filling                          | m <sup>3</sup> | R            | N           |
| 53.13.01             | Removal of unwanted vegetation   | m <sup>2</sup> | T            | N           |
| <b>11</b>            | <b>Bridge surface</b>            |                |              |             |
| 53.02.01             | Sweeping                         | m <sup>2</sup> | T            | Y           |
| 53.06.01             | High-pressure hosing             | m <sup>2</sup> | T            | N           |
| etc.                 |                                  |                |              |             |



## **PRINTOUTS**

### **Inspection Lists/Work Orders**

The work order is one of the most important printouts in the process. It is an inspection list to which quantities have been added.

Before the inspection list is printed from DANBRO, it is checked that all the structures have been registered. The following are then checked:

- The list of components and works is in order
- That a work order, including quantities and products, has been allocated to each structure.

When the inspection list is used on the site, the primary aim is to register the quantity of each work that it is desired to have carried out. In this way the inspection list becomes a work order.

Components/works and gross quantities are also checked, and new components and works are registered if needed. The "location" space is filled in when only a part of a component is to be repaired or there are special circumstances, such as execution on one or more fixed dates.

Experience has shown that by paying attention to the above details, much unnecessary discussion between contractor, consultant and client can be avoided.

If a work is to be carried out several times in one year, the number of times is entered, and a corresponding number of lines are formed on the work orders, on which the contractor can enter the amount executed and certify that the work has been carried out.

## Examples of work orders:

| DANBRO<br>Maintenance – List of work orders  |  |     |   |  |
|--|--|-----|---|--|
|  |  |     |   | Date: 11.03.99                         |
| Structure: 000-0170-0-002.00 UP of P-watercourse, Laesoe, Kaempebro  |  |     | Manager: 0                                |  |
| Road section: 000-0170-0 Skjernvej   |  |     | Km: 14.000                                |  |
| Component/Location   | Work/Product   | T/R | Quantity<br>Total<br>Expected<br>Executed | Year/Date<br>Last executed<br>Executed |
| 11.10 Bridge surfacing<br>Bitumen joint  | 53.07.03 Replacement of<br>bitumen joints<br><br>4.101 Guma 1030 | T   | 80 m<br>20 m                              |  |
| 11.10 Bridge surfacing,<br>Bitumen joint   | 53.08.01 Filling of bitumen joints<br><br>4.101 Guma 1030        | T   | 80 m<br>3 m                               |  |
| 12.00 Expansion joint  | 53.04.01 Hosing of expansion<br>joints                           | T   | 40 m<br>40 m                              | 1997                                   |
| 13.00 Manhole/drain<br><br>The 2 manholes on the<br>bridge are cleaned in April<br>and November.<br><br>The 4 manholes outside<br>the bridge are cleaned in<br>April | 53.05.01 Cleaning of manholes,<br>drains                         | R   | 6 Nos.<br>8 Nos.                          | 1997                                   |
| etc.   |  |     |   |  |

**Cost Estimate/Bill of Quantities**

The cost estimate includes all works to be executed, both those in the Bill of Quantities and those to be carried out on the basis of materials, labour, etc. used.

Unit prices are based on experience (DANBRO price book). At this time it is decided which works can be funded in the year in question, which are to be executed by the management's own staff and which are to be executed by a contractor.

The number of structures on which a given work is to be carried out has a considerable influence on the contractor's unit price for that work. The number of structures involved is given in the cost estimate and the Bill of Quantities (see below).

An example of a cost estimate:

| <b>DANBRO</b>                                      |                                     |                         |                |                  |                       |
|--|-------------------------------------|-------------------------|----------------|------------------|-----------------------|
| <b>Maintenance – Cost estimate</b>                 |                                     |                         |                |                  |                       |
|  |                                     |                         |                |                  | <b>Date: 11.03.99</b> |
| Bill of Quantities work                            |                                     |                         |                |                  |                       |
| Work   |                                     | Total expected quantity | No. of bridges | Unit price (DKK) | Price (DKK)           |
| 53.02.01   | Sweeping                            | 3300 m <sup>2</sup>     | 3              | 2,00             | 6600                  |
| 53.03.01   | Grass cutting                       | 2552 m <sup>2</sup>     | 2              | 2,00             | 5104                  |
| 53.04.01   | Hosing of expansion joints          | 240 m                   | 2              | 45,00            | 10800                 |
| 53.06.01   | High-pressure hosing of surfaces    | 570 m <sup>2</sup>      | 2              | 25,00            | 14250                 |
| 53.07.01   | Replacement of soft joints          | m                       |                | 280,00           |                       |
| <b>Total Bill of Quantities work</b>               |                                     |                         |                |                  | <b>36754</b>          |
| Work to be executed on account                     |                                     |                         |                |                  |                       |
| 53.10.03   | Surface treatment of steel bearings | 8 No.                   | 1              | 1500,00          | 1200                  |
| 53.15.01   | Establishment of embankment facing  | m <sup>2</sup>          |                |                  |                       |
| 53.21.01   | Concrete repairs                    | 72 m <sup>2</sup>       | 1              | 1000             | 72000                 |
| 53.22.01   | Removal of graffiti                 | 462 m <sup>2</sup>      | 2              | 500              | 231000                |
| 53.23.01   | Surface treatment of asphalt        | m <sup>2</sup>          |                |                  |                       |
| Total work on account                              |                                     |                         |                |                  | 304200                |
| Grand total (Bill of Quantities + work on account) |                                     |                         |                |                  | 340954                |

## Overview of Works and Structures

The contractor, the consultant and the client can obtain a wide variety of printouts from the system; one of the most frequently required is an overview of works and bridges. An example of overview of works/bridges:

| <b>821 Hjoerring Commune, Maintenance</b>                        |               |        |                                |                   |
|--|---------------|--------|--------------------------------|-------------------|
| <b>Overview: 53.20.01 Establishment of fascine stabilization</b> |               |        |                                |                   |
| Structure-ID   | Road section  | Km     | Location                       | Expected quantity |
| 821-0037-00-001.00   | Agdrup Bjerge | 2.094  | Western slope, north and south | 8                 |
| 821-0858-00-001.00   | Borupvej      | 1.006  | All 4 corners                  | 12                |
| 821-6742-00-001.00   | Saksagervej   | 0.082  | South-west                     | 2                 |
| 821-6751-00-001.00   | Sakstrupvej   | 3.0476 | All 4 corners                  | 12                |
| <b>Total expected quantity</b>                                   |               |        |                                | <b>34</b>         |

This is just one of many possibilities, and the Road Directorate has received requests for other types.

**Quality Assurance Material**

For this type of work, the completed work orders form the basis of the quality assurance system.

There is also a checking plan with an associated checking form for certain works such as aggregate-filled joints.

| <b>Tender checking plan, Structures</b> |                      |   |                        |  |
|---|----------------------|---|------------------------|--|
| <b>821 Hjoerring Commune</b>            |                      |   |                        |  |
| <b>TENDER CHECKING PLAN</b>             |                      |   |                        |  |
| <b>Work</b>                             | <b>Checking time</b> | <b>Checking method</b>                        | <b>Checking extent</b> | <b>Documentation</b>   |
| Aggregate-filled joints                 | During execution     | Visual<br>Measurement of material temperature | 100%<br>Twice per hour | Checking form for filling aggregate-filled joints is completed (PO5) |

| <b>PROCESS CHECK – REPLACEMENT OF AGGREGATE-FILLED JOINT</b> |           |         |                |    |          |    |                      |               |               |               | <b>Form PO5</b> |         |
|--|-----------|---------|----------------|----|----------|----|----------------------|---------------|---------------|---------------|-----------------|---------|
| FILE:  |           |         |                |    |          |    |                      |               |               |               |                 |         |
| Date   | Structure | Compon. | Joint geometry |    | Priming  |    | Material temperature |               |               |               | Sign.           | Remarks |
|  |           |         | Approved       |    | Approved |    |                      |               |               |               |                 |         |
|  |           |         | Yes            | No | Yes      | No | Time/<br>temp        | Time/<br>temp | Time/<br>temp | Time/<br>temp |                 |         |
|  |           |         |                |    |          |    |                      |               |               |               |                 |         |
|  |           |         |                |    |          |    |                      |               |               |               |                 |         |
|  |           |         |                |    |          |    |                      |               |               |               |                 |         |

**Maps**

For all the parties concerned it is essential to have good maps that precisely indicate the location of the structure. Without such maps, it would take too long to locate a small structure, as the personnel in each administration frequently change and external consultants and contractors are often involved.

Many administrations now use various Geographical Information System (GIS) tools to locate structures.

**CONCLUSIONS**

This article describes the most important elements of a new method of administering routine maintenance.

The useful tool DANBRO, combined with two detailed manuals from Bridge Management with DANBRO (Vol. 4)—Maintenance and Routine Inspection and Tender and Operational Regulations for Structures, constitute the basic components of the system.

The standardized way in which needs are registered (well-trained personnel) and a relatively uniform way of describing the content of the works make the system easy to work with.

Works can be executed either on account or on the basis of a Bill of Quantities, but for both types, a precise allocation of the work together with supplementary remarks contributes to the success of the system. In principle, work orders should be formulated in such a way that the foreman can execute 98% of them without contacting the site supervision.

In addition, DANBRO's product catalogue (approved products) and the work orders' references to previously used products facilitate the planning and execution of the work.

It requires a good deal of work to teach the client, the consultants and the contractors how to use the system, but when the administrators at national, county and municipal levels use the same system, its great advantages make themselves felt within two years of the start of implementation.

The contractor also benefits by the system, as tender documents and specifications are fairly uniform and easy for the maintenance team to follow.

The system has been well received by administrations that have their own "bridge teams." It improves work planning and illuminates a field that was a grey zone in which neither effort nor results were visible.

Future developments in this field will be:

- To link work orders to a geographical information system, so that sites can be visualized and the contractor's planning thereby facilitated.
- For major enterprises, to create a simple tool for administering payments for work and to develop an enterprise management system.
- To make the concerned parties—clients, consultants and contractors—even more familiar with the system.