Inspection, Monitoring, and Priority-Ranking of Bridges

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ABSTRACT

During its service life a bridge must meet a certain quality standard decided by the owner and based on technical and economic parameters. Often it is very difficult to set up these standards and even more difficult to decide on the degree and extent to which bridges in a bridge stock should be repaired and rehabilitated.

Safety is maintained by keeping the structures under observation by means of inspections and by requiring that the repair works be of a high quality. These inspections provide the basis for monitoring, evaluating and priority-ranking the works to be carried out. By introducing different types of bridge inspections and surveys together with the use of a suitable and appropriate Bridge Management System (BMS) for the collected data, the monitoring, evaluating and priority-ranking of a bridge stock have been made easier from both a technical and economic point of view.

Based primarily on technical data but also experience, it is possible to predict the need for funds and budgets for bringing the bridges up to a given quality standard, determined by choosing the economic optimum strategy for repairs within the limited budgets. Following this policy in general, the quality standard after repair or rehabilitation will often vary from project to project due to technical factors not being fully taken into account when economic aspects are the decisive parameters. Because it is costly to achieve both technical and economic aims at the same time and as resources are normally limited the works must be ranked according to a well-defined quality standard and policy. The overriding aim of bridge management is thus to achieve economic optimum solutions for repair, taking the economic interests of society as a whole into account. On the other hand, it is seen in many countries that owners adopt a policy that all bridges must be brought up to a certain quality standard and condition within a given time based only on technical decisions and with limited budgets. Even with these limited budgets, this will not necessarily result in the optimum economic solutions for repair but will only ensure that the whole bridge stock has the same quality standard within a certain time.

The present paper deals with the different ways of describing and administering rehabilitation strategies including the technical and economic consequences for the bridge stock. Data collection through inspections and surveys and entered into a BMS for ranking of bridges for operation/maintenance and repair/rehabilitation is described. Furthermore, the different types of inspections are highlighted together with the degree of precision and detailed information these inspections can provide.

INTRODUCTION

One of the primary aims of bridge management is to maintain safety for the road users. Safety is maintained by keeping the structures under observation by means of inspections and by requiring the rehabilitation works to be of high quality.

The pressure on the road sector is increasing. During the past ten years, the volume of traffic in Denmark has increased by 3–4 % per year. The road network has been expanded, improved and maintained to keep pace with the growth, and a flexible management has contributed to maintaining traffic flow with no reduction in safety.

Passability for road-users at all times is important. It is necessary to carry out preventive measures, have different repair strategies, a proper administration of special transports and emergency plans for ensuring passability.

Environmental aspects such as health, noise, vibration, aesthetics, etc., are topics to be taken care of in a modern bridge management organization, which of course also include service and information to the road users.

Achieving the above-mentioned aims costs money and as resources are limited they must be priority ranked. The overriding aim of bridge management is to achieve economic optimum management, taking the economic interests of society as a whole into account.

For ensuring the safety of bridges on a day-to-day basis and the passability for road users, it is necessary for the bridge management authority to establish a monitoring system covering the whole bridge stock. There are two main activities when creating a good technical and economic monitoring system. The first is to define, establish and implement an inspection system. The second is to develop a Bridge Management System as a tool for handling all the information stored in a database.

By organising these two activities it is possible to obtain outputs concerning:

- Needs for repair and maintenance
- Predictions of deterioration and consequences
- Options for repair
- Ranking and optimization of limited resources
- Estimates of overall costs and budgets

The direct monitoring of bridges is done by means of inspections. The data and photos collected on the inspection date are a total registration, check and monitoring of the actual condition of the bridge that day. It is momentary monitoring. The situation could in fact be totally different before the inspection data are even stored in the database due to, e.g., impact from traffic or the environment. Fortunately, this situation seldom arises.

The Danish inspection system involves a frequent monitoring due to having several types of inspection. From special inspection every 5 to 10 years, principal inspection normally every 2–4 years, routine inspection on average once a year over to the roadmen's check at least once a week, the bridges are covered by a more or less permanent safe monitoring system. This is one of the major reasons for the success of the Danish system abroad.

Furthermore, an inspection system such as the Danish is established with the aim of supplying the management authority with reliable and prompt information on the actual condition of the bridge stock. Request for any type of information can be answered at short notice using the various options available in the BMS.

INSPECTION OF BRIDGES

The main objective of inspections is to ensure that traffic safety is maintained at all times on the highway network. Other objectives are to monitor and predict the changes in condition of structures including registration of damage and defects on bridge components, and to give the management authority the necessary technical and economic basis for planning of improvements, repair, cleaning and maintenance work, in order to carry out these activities in an optimum way throughout the structure's service life.

Different types of bridge inspections on site are the essential activities to be included in any kind of bridge management.

The inspections will normally provide the basis for a satisfactory monitoring, evaluation and ranking of repair works on structures if they are well organized according to the regulations. The Bridge Management System (BMS) is used as a tool for the management and administration of information and is the other important part of a monitoring system.

Basic Rules

For the bridge owner it is of the greatest importance to build up an inspection system suitable for the condition of the present bridge stock and for the required information level it is intended to be operating at, both technically and politically. There will always be some basic rules to be followed when preparing and setting up a tailor-made inspection system and BMS for an organization. Requirements must be formulated and at least the following considered:

Codes and Standards to Be Referred To and Used

National standards and codes must be the basis, but application of international standards such as Eurocodes (CEN) and AASHTO are often recommendable, especially in countries with infrastructure in poor condition. Bridge owners are making a technical decision on the quality standard acceptable for the whole bridge stock by selecting the standards to be followed.

Detailing the Information Collected

Well-defined rules for which data are to be collected and in which form must be clearly stated in guidelines for the inspectors.

Use of Modern Equipment and Tools

Decisions should be made concerning how advanced investigation methods and tests should be used for registration and verification of condition data in relation to simple engineering judgement by experienced staff.

Comprehensive Guidelines for Inspections

A detailed description of any aspect of the inspection work must be given in a guideline to ensure a uniform performance, independent of the personal influence of the inspector.

Quality Assurance of the Collected Data

Rules for quality assurance of data must be established and organized by the bridge owner. A "Quality Activity Plan" must be defined and implemented covering all the activities from collecting of data until final presentation of reports etc. Requirements for the inspectors must be included in a QA plan.

The Database System for Storing Inspection Data

Requirements for the database system to be used are formulated by the bridge owner and his consultants. Demands, wishes and technical possibilities are constantly changing and developments in the area of information technology (IT) are very rapid. The market for database systems is now huge. The "lifetime" of a new database system today should not be expected to be more than 10 years.

Computer Tools for Processing Data

The basis software for a BMS should be tailor-made for the bridge owner, taking into account all the demands, requirements and needs. There are many possibilities for creating tailor-made software. Whether to include ready-made software, e.g., MapInfo, ScanPhoto or Microsoft products, or prepare connections to other media such as Internet or TV/Video must depend on the bridge owner and his needs.

Management and Execution of the Activities

To achieve the objectives of the inspection system requires an organization with a well-defined and complete description of responsibilities and tasks for the staff (who does what when). Education of staff must be continuous, keeping the inspectors up to date with the latest technology and developments especially in the areas of IT and BMS.

Flexibility for Further Development and Improvements

As the technical possibilities are changing very rapidly, it is recommended to establish a system with a certain degree of flexibility. The software should be easy to change if new demands are made on the functioning of the BMS, e.g., from PC-based to network version.

Form for Final Data

Inspection data should be prepared and collected with due regard to the level in the organization it is intended for. The executive, planning, administrative or maintenance level each require a different form of presentation. For instance, the use of photos and video recording must be in accordance with the desired layout of reporting.

Modular Approach

As a consequence of the above-mentioned items and the realisation that different administrators have different needs, an inspection system and BMS should always be prepared as modular with inter-relations between the different activities.

Since 1988 a tailor-made modular BMS for storing, processing and reporting of inspection data has been used in Denmark. Only minor changes have been made to the inspection procedures, but the BMS has been improved several times as new technology has become available on the market.

The Danish BMS is based on data from four different kind of inspections, all described in national codes. The inspection types are all separate activities, but of course with inter-relations between them. The four types are as follows:

- Roadman check
- Routine inspection
- Principal Inspection
- Special Inspection

In the following is given a short presentation of the four inspection types as they are presently used in Denmark.

Roadman Check

The roadman check of bridges is normally performed once a week with the objective of monitoring the whole infrastructure closely in the time between the principal and routine inspections. The check ensures day-to-day traffic safety and serviceability for the road-users and contributes considerably to the monitoring system.

The roadman check of bridges is performed as part of the regular inspection of the highway network. It includes a check of the bridge components directly visible from the inspection van.

Bridges are checked for any sudden damage or deterioration such as signs of settlements or displacements, damage on slabs, girders, railings, columns or piers due to impact from traffic, erosion of slopes etc.

For the registration of any kind of failure or damage observed, specially prepared forms are filled in, photos taken and the material handed over to the responsible engineer for further action. The registrations can also be stored in the database if necessary.

The roadman check is performed by a contractor on the national highway network in Denmark.

Routine Inspection

Frequent routine inspections are carried out in order to monitor the safety and the day-to-day serviceability of the bridges, for the planning of routine preventive maintenance work for avoiding serious and costly damage development.

On the national highway network in Denmark this type of inspection is executed by bridge inspectors at least once a year.

As a tool for planning and monitoring of the maintenance work, the routine maintenance module was developed and included in the BMS. The use of this module ensures that the maintenance works are carried out systematically and optimally in accordance with the needs and allocated funds.

The module comprises a list of standard bridge components which is more detailed than the one used for principal inspection. For each component, standard works are linked with corresponding unit prices and with relevant specifications for the material to be used.

For each bridge, the principal dimension such as length and area of each standard component is registered and stored in the database. From the maintenance module a list of possible maintenance work is then printed for the inspector. During the routine inspection the need for each work is registered.

Based on these registrations that are stored in the database, work orders for each bridge are automatically generated and printed, stating the type of work, the expected extent, a brief description of where to execute the work on the component and the materials to be used.

Having completed the work, the maintenance crew foreman signs the work order including a registration of the extent of the work executed and the date of execution. The signed work orders are collected and used for monitoring the progress of the work and for payment.

The maintenance module also comprises facilities for preparing a Bill of Quantities for tendering based on needs for maintenance registered during the inspections. The Danish Road Directorate prepares tender documents in this way every three years, having the work carried out by a prequalified contractor.

Principal Inspection

The principal inspection is the key activity in monitoring the condition of bridges in the Danish BMS. All the activities leading to the final choice of a rehabilitation strategy for a damaged bridge are initiated at this stage. The principal inspections are carried out by a highly experienced bridge engineer.

The principal inspection is a visual inspection of all visible parts of the bridge. The purpose is to maintain an overview of the general condition of the whole bridge stock, and to reveal significant damage in due time, so that rehabilitation works can be carried out in the optimum way and at the optimum time, taking safety and economic aspects into consideration.

For the inspection, the bridge is divided into a fixed number of standard components, one of which is "the bridge in general." For each standard component the following is registered:

- A condition rating, ranging from 0: "No damage/As new" to 5: "Ultimate damage/complete failure of the component"
- A short description of significant damage (less significant damage is not noted)
- Need for minor maintenance and cleaning (Yes/No)

- Need for Special Inspection, type A or B (A: Technical and economic analysis, B: Economic analysis)
- Need for repair works (type of work, extent, cost estimate, optimum year of execution)

Damage which does not require remedial action is not noted in the inspection report, and in any case, the damage is briefly described. A special inspection will always be carried out before major repair works, including a detailed damage description.

As a help in making a cost estimate for repair works, the inspector is provided with a catalogue of unit prices of common works.

An essential part of the principal inspection is to determine the year of next inspection for the individual bridge. The interval may vary between one and six years depending on the condition of the bridge. If a bridge is in a bad and still deteriorating condition, the interval may be as short as one year. If the bridge is new and in good condition, the interval may be up to six years. This is part of a general policy of concentrating the effort on the areas that really need attention, thus getting the most out of the limited funds for bridge maintenance. At this point, the experience of the inspector is very important.

Each year a list is printed specifying the bridges to be inspected in that year.

The main output from the principal inspection module is:

- Various statistics on the general condition of bridges
- Cost estimates for all rehabilitation works 10 years ahead
- List of bridges to be inspected in a specified year
- List of bridges that require special inspection
- Statistics on the performance of routine inspection

Recently a photo module has been included in the BMS, making it possible to view photos taken during inspections directly on the PC monitor. The photos are also printed with the inspection reports.

For very large bridges, tunnels, ferry berths and other special structures for which the fixed division into standard components is not applicable or sufficient, a special module has been added. In this module, components can be specified in a four-level hierarchical structure. For each component and component level, condition ratings and costs estimates for routine maintenance and rehabilitation works can be registered and summarized.

Special Inspection

Normally, special inspections are initiated at the principal inspection, when the principal inspector is not certain about the cause, the type and extent of damage or the proper rehabilitation method.

Special inspections are always carried out by engineers with experience in deterioration mechanisms, bearing capacity, advanced inspection methods and considerable knowledge in the field of rehabilitation design. The special inspection comprises both destructive and non-destructive tests carried out in-situ, as well as laboratory tests on collected samples. Based on the results of these tests, the state of damage is assessed as well as its probable future development, and various rehabilitation strategies are evaluated.

The full range of relevant strategies to be considered may normally be divided into four types:

- Make a thorough repair now, bringing the bridge back to "as good as new" condition.
- Make superficial repairs now in order to postpone major repairs by several years.
- Do nothing now, wait until the bridge or the component in question is no longer safe, then replace it.
- Do nothing at all until the bridge is no longer safe, then close it and accept the road-user costs that follow.

Within each of these strategy types, the special inspection engineer determines in detail the type of work to be executed and the optimum time for it, seen only from a technical point of view. Finally, the total number of relevant strategies is reduced to a few significantly different ones, each the economic optimum within its type, by taking repair costs into consideration.

A special inspection report ends with a detailed description of the relevant selected repair strategies including recommendations and conclusions. The data are presented in a standardized form ready for ranking procedures of bridge repairs and optimization of allocated funds.

PRIORITY RANKING

Ranking of bridge maintenance works is influenced by many factors, such as political influence, differences in the importance of the road, condition of the bridges, the bearing capacity of the bridges, etc.

It is often necessary to choose between various strategies. Shall one choose an expensive repair with a long service life or a cheaper repair with a short service life? Another problem is the time at which the repair should be carried out. Should it be done as soon as possible, can it be deferred, or can it wait until the structure is replaced?

Political influence can be more or less direct and can be impossible to predict. The focus can within a very short time switch from maintenance of the transport sector to other areas within the public sector such as health insurance, education etc., which of course depends on how the main political currents are at the moment. The owners of the bridges sometimes demand higher aesthetic standards and better condition of bridges in urban areas.

Some roads and railways are more important than others. A bridge carrying a main road is very important and should function without any problems. Main traffic arteries often cross national boarders and the transport sector is very dependent upon their functioning. But there are also differences in the demand for quality when for instance comparing main roads with secondary roads. Often there is a lower quality standard on the secondary roads despite the fact that it is close to where people are living.

In the following is described two different methods for ranking bridges, the net present value method and the point ranking method. The first is a method that results in cost information on the rehabilitation strategy for the whole bridge stock. The second method can be a technical help or an alternative method to the economic method.

Net Present Value Method

In the net present value method, the costs of repairs, traffic diversions, traffic noise and pollution; operation and maintenance are calculated year for year within a chosen time-horizon; the timing of each cost is based on the service life of each repair. The annual costs are then discounted back to the initial year using a given discount rate. In this way the present value of each year's expenditure is obtained.

By summing the present values, a value for the strategy in question is obtained that can be compared with the corresponding value for other strategies. The strategy for which the cumulative present value is lowest is the economic optimum for the structure considered in isolation.

The cumulative net present value makes it possible to compare strategies in which the costs are spread over varying periods, as all costs are converted to the initial year. The further in the future a cost falls due, the lower is the present value of that cost. This effect is proportional to the discount rate adopted. To put it simply, the present value is the amount that must be deposited in the bank today to cover a cost that will fall due at the time the repair is carried out.

The present value is calculated by

$$I_n = I/(1 + r)^n$$

where I_n is the present value of a cost I in the year n
I is the cost in the year n based on the chosen price level (normally current price)
n is the number of years until the cost falls due
r is the discount rate, decided by the management authority.

The net present value calculation is thus carried out in fixed prices (those of the initial year) with a chosen price level and a chosen discount rate.

Parameters for Present Value

In an economic evaluation of alternatives, the most important parameters are:

- The costs of repairs and traffic inconveniences.
- The equal-value element in the repair strategies.
- The lifetime of the structural components.
- The time-horizon of the calculations.
- The residual value.

- The time at which the repair is carried out.
- The discount rate.

Costs

The cost of each repair strategy within a given time-horizon is calculated, the following items being taken into account to the extent relevant:

- Repair costs, which include the costs of the contractor and the consultant.
- Client supply items and any railway costs that may be involved.
- Costs of inconvenience to road-users and other costs to society (e.g., relaying of cables and pipes).
- Any operational costs that have an appreciable effect on the choice of repair strategy.

It should be noted that costs to society are not included in the budgets, but are used solely in economic comparisons of strategies.

Repair Strategies

Several repair strategies should be investigated for each structure. To make an economic comparison between strategies, they must result in the same increase in the value of the structure. If a strategy involves a rehabilitation of the structure in the form of a strengthening or extension (e.g., replacement of an old safety-barrier with a new one), the value of the improvement shall be assessed, and a similar improvement must be included in the other strategies if they are to be comparable.

Service Life

The service life of the structural components in question are estimated for each strategy. They are estimated on the basis of experience with the various methods included in the strategies. The estimated service life takes the expected maintenance of the component into account. Safety considerations can reduce the service life relative to that estimated on the basis of repair and maintenance; e.g., replacement of a functioning but obsolete safety-barrier by a new safety-barrier.

Time-Horizon

The time-horizon is usually that of the repair with the longest service life. To make the various repair strategies comparable from the economic point of view, the same time-horizon must be used for all of them. The selected time-horizon should be long enough to make the present value of expenditure beyond the horizon insignificant. The normal time-horizon is 25 years.

Time of Repair

The time at which the repair is to be carried out is determined on the basis of experience. Postponement of a repair will usually result in further damage and consequently increased repair costs later. The time of execution is thus based on the economic optimum service life of the structural component, and is chosen so that the present value of each repair strategy is a minimum. It is recommended to fix the times of execution of a number of related repairs; the repairs should be considered as a group in order to reduce general costs, e.g., for traffic diversions.

Budgetary limitations may require a postponement of the above-mentioned times of execution. This means that the present value of the repair can increase, as the cost of repairing an increased amount of damage and possibly also the cost of increased traffic inconvenience may outweigh the economic gain resulting from the postponement.

Residual Value

A consequence of using the same time-horizon for several strategies will often be that when the horizon is reached, there will be a residual value because the lifetime has not expired. If the value declines linearly with time, it is easy to calculate the residual value. Other forms of decline are possible, e.g., a parabolic curve, corresponding to a slow decline in early years and a rapid decline later. However, this will normally have little influence on the calculation, so that a linear decline can be used in most cases.

In present value calculations, the residual value is discounted and deducted from the cumulative discounted cost.

Point Ranking Method

As described above the net present value method gives information on the cumulative costs over a period, and these costs are based on the engineer's judgement from case to case and much information is hidden in the cumulative costs of each rehabilitation strategy. If it is necessary to have more detailed information on changes in condition, bearing capacity or passability, the point ranking method can be an alternative or supplementary method.

The point ranking method, which calculates the final priority-ranking point, *PR,* is based upon the condition points, P_{con}, the load capacity points, P_{cap}, and the clearance points, P_{cle}, and can be generally described as:

$$PR = W_{rd},\max * W_{con} * P_{con} + W_{rd,overpass} * W_{cap} * P_{cap} + W_{rd,underpass} * W_{cle} * P_{cle}$$

The final ranking of the structures may—according to the current maintenance policy—be influenced by the condition rating, determined by deterioration, malfunctioning, aesthetics; the load capacity rating, determined by the safety level; and the clearance according to the requirements for special transports.

This policy may be changed from year to year. Therefore, the decision must be reflected in independent weighting factors for the condition, W_{con}, for the capacity, W_{cap}, and the clearance, W_{cle}, of the structures.

It is not necessary to vary these factors from one area to another because the importance of the road is given by its weight (*W*).

Connected to the structure are the weights of the roads: the maximum weight, $W_{rd,max}$, which is based on the maximum weight of one of the roads allocated to the structure, the general road weight of the road passing under the structure, $W_{rd,underpass}$, and the weight of the road passing over the structure, $W_{rd,overpass}$.

The road weights basically reflect the amount of traffic on specified parts of the roads, but also the importance of the road, for instance, if the road is a main road carrying heavy traffic across the border.

Generally the weights are chosen by the management authority. When carrying out a sensitivity analysis on the ranking of the structures for rehabilitation, the ranking is recalculated with different weights, both at superior and lower bridge component level.

Condition Rating Point Model

Based upon the condition marks, $M_{con,component}$, for components and the condition weight of components, $W_{con,components}$, the condition point, P_{con}, is calculated as the maximum value of each of the products:

$$P_{con} = \text{max value of } \{M_{con,component} * W_{con,component}\}$$

The condition marks are evaluated at the principal inspection and/or at the special inspection. The condition marks are given to all major components of the bridge such as wing walls, abutments, piers, bearings, superstructure, parapet, road components etc. The range of the condition mark is 0 to 5. A condition mark of 0 indicates a component with very little damage and 5 indicates a component in very poor condition.

The condition mark reflects the following:

- The nature and degree of the damage.
- The extent of the damage.
- Whether the component can fulfil the requirements for its functioning.
- Whether the component has a negative influence on other components or users.

The importance of the different bridge components for the service life of the whole bridge has to be taken care of by allocating a condition weight, $W_{con,component}$, for each component. This means that it is possible to have different weights for the different bridge components, for instance the superstructure can be weighted higher than the wing walls. The weight of a component shall always be less than or equal to the weight of the superior element.

Load Capacity Rating Model

This model calculates the load capacity point, P_{cap}, based upon the load capacity mark, $M_{cap,component}$, and the component capacity weights, $W_{cap,component}$, of the bridge components.

The load capacity mark is calculated for each bridge on the basis of current load capacity and the current loads. The marks 0, 3 and 5 are used according to the following:

- If the vehicle class is less than or equal to the inventory class of the bridge the load capacity rating mark is 0.
- If the vehicle class is higher than the inventory class of the bridge but less than or equal to the operating class of the bridge the load capacity rating mark is 3.

- If the vehicle class is higher than the operating class of the bridge the load capacity rating is 5.

According to the above mentioned classes every bridge must be rated to two levels:

1. Operating class is the absolute maximum permissible load to which the structure may be subjected.
2. Inventory class is the load level which can safely utilize the structure throughout its service life.

The importance of the different components for the safety of the whole bridge shall also be taken into account. This is carried out by the component capacity weights, $W_{cap,component}$, determined for each component. The weight of a component shall always be less than or equal to the weight of the superior component.

The load capacity point, P_{cap}, is calculated as the maximum value of each of the products:

$$P_{cap} = \text{max. value of}\{M_{cap,component} * W_{cap,component}\}$$

Clearance Rating Point Model

This model calculates the clearance point, P_{cle}, based upon the clearance mark for the whole bridge. The clearance mark is calculated for the bridge on the basis of the current headroom clearance. The mark is normally 0, 3 or 5.

CONCLUSION

Budgetary

Budgetary constraints usually make it impossible to carry out all repairs at the economic optimum time. It is therefore necessary to priority-rank the optimal repairs.

In formulating a repair strategy it is standard practice in Denmark to calculate the increase in costs that would result from a postponement. The cost increase is typically due to increase in the amount of repair work or to traffic restrictions in the postponement period.

Rehabilitation is carried out on the structures which turn out to have the highest increase in cost growth (often an accelerated deterioration) and is therefore the most profitable investment.

An iterative process is often necessary to determine which bridges should be rehabilitated and which should be postponed, and it is necessary to use powerful computers for these calculations. Subsequently it is always necessary to critically evaluate the listed bridges and repair methods; this can only be done by experienced engineers.

This evaluation must take into account all the involved factors, such as aesthetics, environment, noise, political influence, the importance of the road, safety, passability, etc.

New Developments

Apart from using inspections and BMS, various installations and monitoring systems are mounted on certain structures in order to evaluate the condition and operation of the structure. This information helps the engineer to evaluate the development of the damage and to choose the right rehabilitation strategy.

It is very important to develop new methods to monitor bridge condition, have research projects to give information on deterioration mechanisms, etc. The major bridge owners in Denmark are active partners in both national and international research projects with participants from consultants, research institutes and universities.

Experience with the Danish System

The Danish system has shown its utility and flexibility abroad as well as in Denmark for several years.

In Denmark a tailor-made BMS has been used since 1988. Concerning principal and special inspection there is more than 25 years of experience in collecting information in this way in Denmark. The system behind routine inspection was developed 10 years ago and has now been fully implemented and used for 6 years.

Bridge Management Systems based on the Danish BMS and "the Danish way" of doing inspections have been implemented by several highway administrations abroad since early 1987. Thailand, Malaysia, Singapore, Saudi Arabia, Mexico, Colombia, Honduras, Spain and Croatia all have a tailor-made BMS in use. Administrations in Bulgaria, Germany, and China have benefited from the Danish inspection system and adapted its ideas directly for bridge management.

The BMS exists in various languages and versions.

Experience from Denmark and the countries where Danish inspectors have been working has shown that it is cheaper and better in the long run to use highly qualified and skilled bridge inspectors to collect all the data on site. The quality of the whole BMS database is totally dependent on the skills of the inspectors at all levels. Economic and technical decisions taken by the management can easily be based on incorrect conclusions drawn by the inspectors when reporting, due to lack of skills. Therefore it is crucial that the inspectors be well-educated and experienced, capable of distinguishing between harmless superficial damage to be handled during routine maintenance and potentially serious damage for which more profound analysis is required. The inspectors must at all times be kept up-to-date with the newest information and innovations within their working field by taking part in training courses and international conferences.

It takes a lot of hard work and sometimes several years to prepare a high quality database. Maintaining the database is in general easier after a few years and the costs decline as the quality of the database improves.