INTERNATIONAL TECHNOLOGY EXCHANGE PROGRAM

Bridge Preservation and Maintenance in Europe and South Africa

U.S. Department of Transportation
Federal Highway Administration

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16. Abstract
The Federal Highway Administration, American Association of State Highway and Transportation Officials, and National Cooperative Highway Research Program sponsored a scanning study of how highway agencies in Europe and South Africa handle bridge maintenance, management, and preservation. The U.S. delegation met with bridge preservation and maintenance experts from Denmark, Finland, France, Germany, Norway, South Africa, Sweden, Switzerland, and the United Kingdom. The scanning study focused on bridge management systems, inspection practices, permit load evaluation and routing, and innovative maintenance practices in those countries. The scanning team's recommendations for U.S. application include establishing several types of and intervals for bridge inspection, and requiring different levels of inspector certification. The team also recommends research projects and syntheses to expand bridge management systems to include all highway structures, incorporate risk assessment in formation of network maintenance programs, evaluate the cost-effectiveness of proactive maintenance, study the success of waterproofing measures for protecting reinforced concrete members, evaluate coordinated maintenance planning for roads and structures to achieve minimum traffic disruption in a corridor, and examine procedures for load rating of bridges.

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Bridge Preservation and Maintenance in Europe and South Africa

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FHWA INTERNATIONAL TECHNOLOGY EXCHANGE PROGRAMS

The Federal Highway Administration's (FHWA) Technology Exchange Program accesses and evaluates innovative foreign technologies and practices that could significantly benefit U.S. highway transportation systems. This approach allows for advanced technology to be adapted and put into practice much more efficiently without spending scarce research funds to recreate advances already developed by other countries.

The main channel for accessing foreign innovations is the International Technology Scanning Program. The program is undertaken jointly with the American Association of State Highway and Transportation Officials (AASHTO) and its Special Committee on International Activity Coordination in cooperation with the Transportation Research Board's National Cooperative Highway Research Program Project 20-36 on "Highway Research and Technology—International Information Sharing," the private sector, and academia.

FHWA and AASHTO jointly determine priority topics for teams of U.S. experts to study. Teams in the specific areas being investigated are formed and sent to countries where significant advances and innovations have been made in technology, management practices, organizational structure, program delivery, and financing. Scanning teams usually include representatives from FHWA, State departments of transportation, local governments, transportation trade and research groups, the private sector, and academia.

After a scan is completed, team members evaluate findings and develop comprehensive reports, including recommendations for further research and pilot projects to verify the value of adapting innovations for U.S. use. Scan reports, as well as the results of pilot programs and research, are circulated throughout the country to State and local transportation officials and the private sector. Since 1990, FHWA has organized more than 60 international scans and disseminated findings nationwide on topics such as pavements, bridge construction and maintenance, contracting, intermodal transport, organizational management, winter road maintenance, safety, intelligent transportation systems, planning, and policy.

The International Technology Scanning Program has resulted in significant improvements and savings in road program technologies and practices throughout the United States. In some cases, scan studies have facilitated joint research and technology-sharing projects with international counterparts, further conserving resources and advancing the state of the art. Scan studies have also exposed transportation professionals to remarkable advancements and inspired implementation of hundreds of innovations. The result: large savings of research dollars and time, as well as significant improvements in the Nation's transportation system.

For a complete list of International Technology Scanning Program topics and to order free copies of the reports, please see the list contained in this publication and at www.international.fhwa.dot.gov, or e-mail international@fhwa.dot.gov.

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The content of this report is the content of the presentation made by scan participants. These talented engineers produced excellent work to share with the scan team. Most figures and photographs in this report are collected from the presentations. Our ability, now, to report this work is due largely to the participants' knowledge, skill and generosity.

Abbreviations and Acronyms

ADT	Average daily traffic
AFGC	Association Française de Génie Civil
ANFOR	Association Française de Normalisation
BAPS	Bids and prioritization system
BASt	Bundesanstalt für Straßenwesen
BCI	Bridge condition index
BMS	Bridge management system
BMVBW	Bundesministerium für Verkehr, Bau- und, Whonungswesen
CETE	Centre d'Etudes Techniques de l'Equipement
CETU	Centre d'Etudes des Tunnels
CSIR	Council for Scientific and Industrial Research
DER	Degree, extent, relevancy
DDE	Direction Départementale de l'Equipement
eGIF	e-Government Interoperability Framework
EPFL	Ecole Polytechnique Federale de Lausanne
FEDRO	Swiss Federal Roads Office
Finnra	Finnish Road Administration
FRP	Fiber-reinforced polymer
GIS	Geographic information system
GPS	Global positioning system
GUI	Graphical user interface
HA	U.K. Highways Agency
HARM	Highways Agency Risk Management
IQOA	Image de la qualité des Ouvrages d'ART
LCPC	Laboratoire Central des Ponts et Chaussées
LCV	Lack of capital value
LRFD	Load and resistance factor design
NDT	Nondestructive testing

PI	Performance indicator
SANRAL	South African National Roads Agency Limited
SETRA	Service d'Etudes Techniques des Routes et Autoroutes
SMIS	Structure management information system
SNRA	Swedish National Road Administration
SO	Special order
STGO	Special types general order
TRL	Transport Research Laboratory
WIM	Weigh in motion

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Executive Summary

BRIDGE PRESERVATION AND MAINTENANCE SCAN

From March 28 to April 13, 2003, a team of U.S. engineers traveled to South Africa, Switzerland, Denmark, and England under the International Technology Scaninng Program to seek information on bridge maintenance, management, and preservation topics. The U.S. scan team included engineers from the Federal Highway Administration (FHWA), State departments of transportation (DOT), a county roads agency, and universities. Scan team members are all engaged in practice or research involving bridge maintenance, preservation, and management. The U.S. team met with more than 50 engineers from nine countries representing national roads agencies, regional roads agencies, research labs, and engineering consultants. Scan team members, and scan participants are listed in Appendix A.

Method

Information was exchanged in a series of meetings with engineers from the countries being studied in the scan. Meetings were held at Pretoria, South Africa; Bern, Switzerland; Copenhagen, Denmark; and London, England. Presenting at these meetings were engineers from the following agencies:

- South African National Roads Agency Ltd. (SANRAL)
- Council for Scientific and Industrial Research (CSIR Transportek)
- Bundesamt für Strassen (FEDRO, Swiss Federal Roads Office)
- Canton Aargau Public Works
- Ecole Polytechnique Federale de Lausanne (EPFL, Swiss Federal Institute of Technology)
- Laboratoire Central des Ponts et Chaussées (LCPC, French Public Works Research Laboratory)
- Bundesanstalt für Straßenwesen (BASt, German Federal Highway Research Institute)
- Danish Road Directorate
- Finnish Road Administration (Finnra)
- Vagverket (SNRA, Swedish National Road Administration)
- Statens vegvesen (Norwegian Public Roads Authority)
- United Kingdom Highways Agency (HA)
- Transport Research Laboratory (TRL)
- Welsh Assembly Government Transport Agency
- Engineering consultants from South Africa, Switzerland, England, and Finland

The scan team visited research laboratories at EPFL in Lausanne, Switzerland, and at TRL in Crowthorne, England. The scan team visited bridges, including the Nelson Mandela Bridge in Johannesburg, South Africa, bridges along the Swiss national roads, and the Oresund Bridge and tunnel linking Denmark and Sweden.

Focus

Topics for scan meetings were established in advance, and scan participants were asked to address these topics in their presentations. The topics are listed below:

- Organizational, policy, and administrative issues, including relationships among agencies (national, local), organization of bridge activities (design, construction, operations, inspection), inventory ownership and management, inventory characteristics (number, type, materials, span lengths), and inspection type, frequency, and rigor.
- Status of bridge management systems (BMS), including economic modeling and forecasting, deterioration modeling, and information technology (databases, architecture, input, data transfer, updating).
- Inspection issues and practices, including typical practices, innovative methods, use of nondestructive evaluation technologies, use of load testing, design for inspection (e.g., accessibility), and "smart" bridges.
- Operations issues and practices, including permit vehicles, load rating and load posting, indicators of performance and their relationship to design and other activities, maintenance, repair, and enforcement.

Findings

A list of notable items from meetings was assembled as the scan proceeded. After meetings at each venue, the team compared notes and identified items with potential to improve U.S. practice. In all, about 100 items were added to the list. Similar items were collected into a list of 24 findings, and the findings were collected into 16 recommendations for further work. (Recommendations, findings, and the complete list of items are in Chapter 3.)

This Report

This report provides a synopsis of findings, a set of recommendations for future work, and a review of the presentations to the scan team.

SYNOPSIS OF FINDINGS

Conceded Roads

In most of the countries studied in the scan, portions of the national road network are either conceded or operated under long-term maintenance contracts. These two forms differ in funding mechanism. Concessionaires usually collect roadway tolls to fund maintenance of roads and structures, and to clear a profit. Maintenance contractors do not collect tolls, but instead are paid directly by national roads agencies. In either form, oversight by national roads agencies ensures conformance to contract specifications. Contracting and conceding are important drivers in the creation of detailed manuals for inspection, maintenance, and repair operations.

Bridge Management Systems—Structures

In most countries the scan team studied, maintenance management systems include all structures that are the responsibility of the bridge engineering staff in the roads agency. Management systems routinely include bridges, retaining walls, tunnels, and sign structures (table 1). Denmark, Norway, and Sweden include all of these plus berths and quays for ferry links in their road networks. Natural similarities exist in approaches to modeling, inspection, and evaluation for all road structures. Management systems can accommodate new classes of structures with new elements, or with new data and interface modules for each class. Several countries have special modules for managing electrical and mechanical systems at bridges. At major crossings, maintenance responsibilities can include toll plazas, control buildings, computer systems, communications systems, sensors (for operations), deicing systems, and traffic signaling and gating.

Table 1. Maintenance management systems and structure domains.

Country	Management System and Structures
Denmark	DANBRO—Bridges, culverts, ferry berths, noise barriers, retaining walls, and sign structures DANBRO+—Tunnels, special structures and their electrical, mechanical, communications, control, and data systems
Finland	HiBris—Bridges, culverts, and pavements on the network level Hanke-Siha—Project-level bridge management
France	LAGORA—Bridges, culverts, retaining walls, and tunnels
Germany	SIB-Bauwerke—Structure and inspection date of bridges, culverts, retaining walls, sign structures, and tunnels. Modules BMS-MV, -MB, -EP—Short-range project and network-level planning Module BMS-SB—Long-range planning at network level (all BMS modules in the development stage)
Norway	Brutus—Bridges, culverts, ferry berths, quays, retaining walls, and tunnels
South Africa	STRUMAN—Bridges, culverts, retaining walls, and sign supports
Sweden	BaTMan—Bridges, culverts, tunnels, ferry berths, quays, retaining walls, sign supports, and other structures related to bridges and tunnels.
Switzerland	KUBA—Bridges, protective structures, and retaining walls. UplaNS—Network-level management of all highway assets.
United Kingdom	SMIS—Structures information system, with associated modules for maintenance management functions for bridges, tunnels, and retaining walls

Bridge Management Systems—Structures and Pavements

Scan countries coordinate maintenance plans for pavements and structures, usually in a final planning step after automated optimization of maintenance programs. Two countries, Finland and Switzerland, have software systems to perform joint optimization of programs for pavements and structures. Finland's HiBris system (the name means Highways and Bridges) replaces two older, separate pavement and bridge management systems. The Swiss system, UPlaNS, will provide coordinated management of all roads assets, including pavements, bridges, walls, and structures.

BMS and Risk

The countries the scan team studied recognize the uncertainty in the observations, assumptions, and forecasts that network maintenance programs are built on. The United Kingdom includes uncertainty directly in deterioration models. Finland's HiBris employs optimization schemes that accommodate uncertainty in data. Other scan countries examine the sensitivity of costs to delays in execution. In all cases, risk is the possibility that new or worsened defects at bridges will hinder execution of the maintenance program. The consequences are higher user costs because of increased traffic delays. A risk-based optimization of maintenance programs recognizes the potential for adverse performance at bridges if maintenance is deferred.

BMS and Reference Bridges

Finland has a reference group of 106 bridges and 26 steel culverts. The performance of the group is closely monitored to improve knowledge of bridge behavior and durability, calibrate BMS deterioration models, and evaluate methods for field testing. Reference bridges are used in training and annual recertification of bridge inspectors.

Condition Ratings and Defect Reporting

Most scan countries define their rating scales in terms of defects rather than conditions so that good condition in elements is revealed in the null sense: the absence of a defect report. All scan countries report two or more categories of information on defects (table 2). Most often, both the severity of the defect and the urgency of repair are reported. Finland and South Africa report the importance of the defect to bridge load capacity. Germany and Norway report the aspect of bridge performance most affected by the defect. Denmark reports the severity of defects and the needed repair action.

Table 2. Defect reporting.

Country	Defect reporting categories
Denmark	0-to-5 condition rating plus inspector's recommendation on repair urgency
Finland	0-to-4 condition rating scale plus importance in load path, severity, urgency of repair, condition of the bridge element
France	1-to-3 condition rating scale. 2E indicates urgent need for specialized maintenance, 3U indicates urgent need for repair, and S indicates a threat to user safety and an urgent need for action.
Germany	1-to-4 condition rating scale plus identification of defect as stable, threat to durability, or threat to traffic safety.
Norway	1-to-4 severity rating scale plus a consequence code (impact on load capacity, traffic operations, maintenance cost, or environment)
South Africa	Ratings in four categories: degree (severity), extent, relevancy (in the load path), and urgency of repair
Sweden	Ratings in three categories: physical, functional, and economic condition (related to extent of damage)
United Kingdom	1-to-5 severity rating plus A-to-E extent rating

Maintenance Actions

The countries the scan team studied define several levels of actions for structures. Routine actions, such as washing decks, clearing vegetation, and removing debris, are taken at regular intervals at all bridges. Minor repairs, such as concrete patching and spot painting of steel, are applied as needed and rarely require engineering design. Larger repairs, rehabilitation, or improvement projects require engineering design and are subject to automated programming by the maintenance management system.

Most countries identify a maintenance budget for routine actions and minor repairs. Funding for maintenance ranges from 0.5 to 1.5 percent of the replacement value of bridges. Large repairs, rehabilitation, and improvement are in a separate capital budget. Like the United States, each scan country has a backlog of repair and improvement projects. Backlogs range from 6 to 18 annual budgets for capital improvements.

Zero-Maintenance Concept

Swiss FEDRO is working on a zero-maintenance concept for maintenance programming. On a project level, the Swiss effort seeks technologies that improve the durability of bridges, allowing longer intervals between repair projects. On the network level, Swiss maintenance planning is coordinated to minimize impacts on traffic operations.

The Swiss program UPlaNS supports improved maintenance planning of the Swiss National Roads. The network of about 1,800 kilometers (km) of national roads is divided into maintenance sections. Maintenance planning and execution is constrained to the following:

- The minimum distance between two maintenance sections with traffic restrictions is 50 km.
- The maximum length of a maintenance section is 15 km.
- The minimum maintenance-free period for each section is 5 to 25 years (20 years on average).

A maintenance project, when executed, must address all needs both in roads and structures in the section, and must prepare the section for 20 years of maintenance-free operation.

Maintenance Priorities

Priorities for maintenance and repair projects are largely determined by engineering judgment. In France, this process is explicit. Engineers in departments (state-level) propose projects and their priorities. Projects are reviewed by regional supervisors for final disposition and funding. Danish practice is similar. Inspectors report the urgency of repairs. All such reports are collected at the Danish Road Directorate and a network plan is formed. Other scan countries develop plans using a computed priority indicator. These computations implicitly rely on engineering judgment. In each there is a condition rating that is a codified input of engineering judgment. These ratings are variously named relevancy (South Africa), or time to repair (Norway), or to time to impact service (Finland). In all cases, these codings have great influence on the outcome of the priority computation.

Performance Indicators

Performance indicators reveal bridge health, average network health, and priorities for maintenance. Performance indicators are cardinal values in priority ranking.

Table 3. Performance indicators.

Country	Indicator
Finland	KTI, a repair index based on defect severity and ADT UTI, a rehabilitation index based on functional deficiencies
South Africa	Ic, a condition index for defects BCI, a bridge condition index combining the defect values, Ic
Sweden	LCV, the lack of capital value as a fraction of bridge replacement cost
United Kingdom	Network indicators for load capacity, lane restrictions, and severe defects Project indicators for visual condition, reliability, availability, and outstanding maintenance

Performance indicators are the dependent values in deterioration models. Sweden ses lack of capital value and an exponential deterioration model. South Africa computes a bridge condition index (BCI) for each bridge and a model of linear decrease in BCI over time.

Finland uses two performance indicators. The repair index is a weighted combination of condition ratings that establishes priorities for repair projects. The rehabilitation index responds to functional deficiencies, and can indicate a need for improvement rather than repair.

France and Germany use condition ratings to track average conditions in the network. France tracks the population of bridges with 2E or 3U condition ratings. A 2E rating indicates an urgent need for specialized maintenance. A 3U rating indicates an urgent need for repair or strengthening. Germany tracks the average condition rating for bridges in its network.

Manuals

Scan countries have manuals and guides for rating, inspection, maintenance, and repair of bridges (table 4). All are worthy of study. Norway's inspection manual is a thorough treatment of defects, their measurement and evaluation, probable causes, investigation procedures, methods of monitoring, and methods of repair. France has guides to repair methods and certified repair products. Germany has a compendium of testing method for materials. Finland has a set of guides collectively called SILKO that address discovery of defects, methods of inspection and measurement, acceptable condition, repair procedures (step by step), and basis for acceptance of repairs. SILKO is a resource for engineers and maintenance crews, as well as a standard for maintenance contractors. Required performance in bridges, methods of inspection and measurement, repairs, and acceptance of repairs are all defined.

Table 4. Manuals and guides.

Country	Use	Publication
Finland	Maintenance Inspection	SILKO Guides Inspection Manual Inspection Guidelines
France	Inspection	*Instruction Technique pour la Surveillance et l'Entretien des Ouvrages d'Art* (IT-SEOA) *Image de la Qualité des Ouvrages d'Art* (IQOA)
	Repair	*Choix et Application des Produits de Reparation et de protection des Ouvrages en Beton* *Référentiel Pour Les Produits De Réparation* *Mise En Peinture Des Bétons De Génie Civil*
	Repair, Strengthening	6 AFNOR standards 1 AFGC recommendations on use of FRP
	Repair Products	AFNOR standards and certification reports
Germany	Inspection	DIN 1076, *Inspection And Testing Of Engineering Structures In Connection With Roads* Guideline RI-EBW-PRÜF *Recording And Assessment Of Damages*
	NDT	ZfP Bau Kompendium
Norway	Inspection	HB 147: Guideline for bridge management HB 129: Inventory Handbook HB 136: Inspection Handbook
Sweden	Inspection	1996: 35E Bridge inspection manual 1996: 38E Measurement and condition assessment of bridges 1996: 37E Schedules of codes
United Kingdom	Series	BD standards and BA technical notes on a range of bridge engineering topics

Inspection—Types and Training

Scan countries employ routine inspections of two or more types, ranging from frequent, cursory inspections to less frequent, thorough inspections. Inspection personnel differ, too. Little training is required for cursory inspection, while thorough inspections may require personnel with formal training as bridge inspectors, engineering education, and professional licensing. Inspection types, intervals, and inspector qualifications are shown on the next page.

A principal inspection ("general" in Finland, "major" in Germany, Norway, and Sweden) is a thorough, arms-length visual inspection comparable to a biennial bridge inspection in the United States. Principal inspections occur every 5 to 6 years in most scan countries. The interval is variable. Inspectors can recommend a shorter interval to the next principal inspection if bridge conditions warrant. Principal inspections identify conditions of all bridge components, and note all defects. Principal inspections may also require that inspectors recommend repair actions, note the urgency of repairs, and estimate costs.

Table 5. Bridge inspections.

Country	Inspection	Interval	Inspector
Denmark	Daily		Road patrol
	Semiannual		Road patrol
	Principal	6 years	Road Directorate trained inspector
Finland	Annual		Road maintenance foremen
	General	5 years	Finnra certified inspector
	Basic (reference bridges)	5 years	Finnra certified inspector with an engineering degree
France	Routine	Frequent	Road maintenance crew
	Annual		French local agencies
	IQOA Condition Evaluation	3 years	Local agencies for bridges meeting current design standards and trained inspectors for non-current bridges
	Detailed	3 to 9 years (6 years on average)	French certified inspector
Germany	Superficial	3 months	German trained inspector
	General	3 years	German trained inspector
	Major	6 years	German trained inspector
Norway	General	1 year	General knowledge of bridges
	Major	5 years	Civil engineering degree plus general knowledge of bridges
South Africa	Monitoring	Frequent	Road maintenance crew
	Principal	3 to 5 years	Licensed professional engineer with experience in bridges
Sweden	Regular	Frequent	Maintenance contractor
	Superficial	6 months	Maintenance contractor
	General	3 years	SNRA trained inspector
	Major	6 years	SNRA trained inspector
Switzerland	Principal	5 years	Experienced bridge engineer
United Kingdom	General	2 years	Training and quality control by engineering consultants
	Principal	6 years	Training and quality control by engineering consultants

General inspections ("simple" in France) occur at 1-to-3-year intervals. General inspections note the growth in known defects (that is, known from a previous principal inspection) and seek significant new defects.

Superficial inspections are quick checks for significant new defects. Superficial inspections occur twice or more each year. Superficial inspections are also made after accidents, floods, or other severe events.

Inspection practice in scan countries relies on two or more types of inspections, and two or more levels of inspector qualifications. Infrequent, thorough inspections can be adequate if they are supplemented by frequent, minor inspections. Frequent checks provide an essential assurance of safety.

Inspector Training

Road agencies in most scan countries provide training for inspectors, and have varying requirements for engineering education, experience, and professional licensing (table 6). Minor, frequent inspections usually require no special qualification of inspectors. Principal inspections have formal requirements for personnel.

France provides inspector training in a set of modules, each focusing on a type of bridge. Inspectors may work only on bridges within the domain of their training. In Finland, inspectors are recertified annually in field trials. In Germany, inspectors must attend an annual workshop.

Table 6. Inspector qualifications.

Country	Training	Certification
Denmark	Mentoring by experienced inspectors	Informal
Finland	4-day course, 2-day field tests, and annual field testing	Finnra examination
France	Training in 6 modules	Three grades: inspector agent, inspector, and project manager. Inspectors and project managers are examined by committee.
Germany	1-week course	Certification based on training, engineering education, and bridge engineering experience
South Africa	Training courses by consultants	SANRAL requires PE license, bridge experience, and inspection training.
Sweden	SNRA training course	Engineering degree, bridge experience, and training

Inspection—Testing and Monitoring Methods

Scan countries all use field testing and sampling methods to further validate the findings of visual inspections. Use is ad hoc. Testing programs are created to address needs at specific projects. The scan countries all use sensors to assure safety in bridges with known problems. The United Kingdom and France have used acoustic monitoring to track wire breaks. The U.K. application was to prestressing tendons. France monitored wire suspension cables. In both cases, the count of wire breaks was directly related to loss of strength. Bridges were kept in service during repairs, and load capacity was closely and quantitatively monitored to assure safety.

Finland uses sampling and field testing to track behavior of reference bridges. These bridges are representative of Finnra's bridge stock, so findings in the reference group are relevant to the rest of the network. Finland is experimenting with permanent sensors to monitor conditions in bridges and track deterioration throughout service life.

Switzerland reports good correlation of concrete permeability with durability. Work at EPFL focuses on the use of the Torrent meter to measure concrete permeability in the field. South Africa also examines concrete permeability, using an oxygen permeability test in the lab rather than a field test.

France makes frequent use of field tests. Many of these tests are directed at verification of prestress levels. The crossbow test, an imposed lateral force deflecting a prestressing strand or wire over a fixed gage length, provides a direct measure of prestress tension. Flat jacks offer a direct measure of stress levels in concrete members. Decompression moment is a controlled load test method that yields the moment necessary to offset precompressions in concrete members. Support jacking offers a verification of secondary moments in statically indeterminate bridges, and this too yields an estimate of prestress force.

Sweden records elevations of survey pegs during inspections (pegs are required on all new bridges). Comparison with elevations on as-built plans reveals movements.

Finland, Norway, and Sweden employ sensing systems on bridges at seaports to detect high winds, ship impacts, or other events that require bridge closure.

Permit Loads

Scan countries have legal limits on truck loads, and offer permits for abnormal loads. Evaluation of abnormal loads and enforcement of limits on trucks vary among countries. Germany has no enforcement of load limits. South Africa houses law courts at truck weigh stations for prompt action on violations.

Computer systems for automated evaluation and/or routing of permit loads are used by Finland (Eriku), and Switzerland (KUBA-MS). Data on load and clearance limits for bridges are available in Denmark's bridge management systems. BMS in Switzerland has data on load limits. Maps for dedicated routes for permit loads are available in Denmark (via the Internet), and South Africa.

RECOMMENDATIONS

Ready for Implementation

The scan team believes the following topics have potential for adoption into U.S. practice:

- **Management of roads structures.** Most scan countries use automated programs for maintenance management of retaining walls, sign structures, and most other roads structures in addition to bridges. Procedures for element-level modeling and condition reporting that are familiar for bridges can be readily extended to include other structures.
- **Management of special structures.** Some bridges have electrical, mechanical, data, or control systems necessary to traffic operations. These include movable bridges with hydraulics, signals, and gates, and major bridges with weather sensors, traffic monitors, signals, gates, toll plazas, maintenance buildings, and maintenance equipment. Maintenance management systems can be expanded with databases and software modules to manage the facilities and equipment for special structures.

Syntheses

For the following topics, the scan team recommends syntheses be prepared to inform U.S. engineers of the practices in the countries the team studied:

- **Performance indicators.** Numerical indicators of the health of bridges and networks include South Africa's bridge condition index, Sweden's lack of capital value method, United Kingdom's suite of indicators for condition, and Finland's repair index and rehabilitation index. A synthesis will report these performance indicators and note their use in maintenance programming.

- **Design for inspection.** Structural designs can simplify inspection by providing access to components and including devices that can be monitored during service. A synthesis will include the German methods of design review, and the Swedish use of permanent survey pegs.

- **Bridge repair methods and manuals.** A synthesis on publications by scan countries for bridge repair techniques and products will include publications listed in table 4. Translation of manuals into English is needed.

- **Inspection manuals.** Scan countries have excellent manuals guiding the work of bridge inspectors. A thorough review of these manuals in a synthesis is proposed. Translation of manuals into English is needed.

- **Asset valuation.** Each scan country has a method to determine the value of its bridge inventory. Most include the expected current replacement cost. Sweden employs a method called "lack of capital value" that considers the existing conditions of structures. Other countries, such as the United Kingdom, also calculate a reduced value because of the current condition and load capacity. A synthesis of these methods is proposed.

- **Housekeeping maintenance.** Scan countries have programs for routine annual actions to extend bridge service life. Deck washing, debris removal, and vegetation control are among these. A synthesis will review housekeeping actions and report on their effectiveness in extending bridge life.

- **Bridge integrity systems.** For bridges near seacoasts, scan countries employ warning systems that respond to high wind, ship collision with the structure, or other events that may warrant bridge closure. A synthesis on the deployment, operation, and reliability of these systems is proposed.

- **Load rating standardization.** All scan countries have activities in evaluation and routing of abnormal loads. A synthesis will review rating loads, note similarities among these loads, and review procedures for bridge analysis and the use of load tests to establish bridge capacity.

Research Studies

For the following topics, the scan team recommends that a study be conducted to make a complete report of foreign practice, relate foreign practice to U.S. practice, consider the impacts on U.S. practice, address outstanding technical issues, conduct tests, and validate methods as necessary to prepare them for use in the United States.

- **Bridge inspection.** Scan countries use certified inspectors to perform major inspections at 5- or 6-year intervals. Personnel with lesser training perform cursory inspections once or twice a year to assure that significant changes in bridges are discovered. A research study will examine reliable bridge inspection programs and identify the types, intervals, and training required of inspectors.

- **Deck waterproofing systems.** Scan countries report success with waterproofing to protect reinforced concrete members. A research study will review the performance of concrete decks with membranes plus asphalt, and concrete members where sealers are used.

- **Zero maintenance.** Swiss FEDRO is studying a concept of zero maintenance. The concept combines improved durability in structures and coordination of all maintenance activities on a section of road to achieve long periods of unimpaired operation. A U.S. study of the concept will evaluate the costs or savings of this approach, and address technologies needed for such long-range planning.

- **Risk-based bridge management.** The United Kingdom includes uncertainty in deterioration models, and computes the costs for potential traffic delays not anticipated in the network plan for maintenance. Sweden, Norway, and Finland compute the sensitivity of maintenance costs to project delay. In general, the disruption of a maintenance plan because of unexpected failures increases costs and constitutes a risk in the network plan. A study of risk evaluation and the inclusion of risk in network optimization is proposed.

- **Weigh-in-motion.** Some scan countries (South Africa, Germany, France) are considering the use of weigh-in-motion (WIM) to monitor truck loads and enforce load limits. WIM may be used to select vehicles that must be directed to weigh stations for evaluation. Sweden and Switzerland use WIM to monitor axle loads. Sweden plans to establish a national control program for overloads. Switzerland employs data on axle loads to update design standards. A study of WIM use to identify overloads is proposed.

- **Concrete permeability.** Concrete permeability is proposed as a chief measure of concrete durability, since the movement of water and contaminants is an important cause of deterioration. A study of in-service measure of permeability (Torrent meter) and of the correlation of permeability and durability is proposed.

Follow-up

The scan team recommends that a small project be undertaken to collect additional information and report on the importance and potential benefits to U.S. practice of the Swiss FEDRO UPlaNS approach to coordinated management of all roads assets.

The scan team recommends that advances in nondestructive testing, and especially the development of standards, manuals, and guides for testing methods, be monitored on a continuing basis.

Chapter One
INTRODUCTION

From March 28 to April 13, 2003, a team of U.S. engineers traveled to South Africa, Switzerland, Denmark, and England under the International Technology Scanning Program to seek information on bridge maintenance, management, and preservation topics. The U.S. scan team included engineers from the Federal Highway Administration (FHWA), State departments of transportation (DOT), a county roads agency, and universities. Scan team members are all engaged in practice or research involving bridge maintenance, preservation, and management. The U.S. team met with more than 50 engineers from nine countries representing national roads agencies, regional roads agencies, research labs, and engineering consultants. Scan team members, and scan participants are listed in Appendix A.

METHOD

Information was exchanged in a series of meetings with engineers from the countries studied in the scan. Meetings were held at Pretoria, South Africa; Bern, Switzerland; Copenhagen, Denmark; and London, England. Presenting at these meetings were engineers from the following agencies:

- South African National Roads Agency Ltd. (SANRAL)
- Council for Scientific and Industrial Research (CSIR Transportek)
- Bundesamt für Strassen, (FEDRO, Swiss Federal Roads Office)
- Canton Aargau Public Works
- Ecole Polytechnique Federale de Lausanne (EPFL, Swiss Federal Institute of Technology)
- Laboratoire Central des Ponts et Chaussees (LCPC, French Public Works Research Laboratory)
- Bundesanstalt für Straßenwesen (BASt, German Federal Highway Research Institute)
- Danish Road Directorate
- Finnish Road Administration (Finnra)
- Vagverket (SNRA, Swedish National Road Administration)
- Statens vegvesen (Norwegian Public Roads Authority)
- United Kingdom Highways Agency (HA)
- Transport Research Laboratory (TRL)
- Welsh Assembly Government Transport Agency
- Engineering consultants from South Africa, Switzerland, England, and Finland

The scan team visited research laboratories at EPFL in Lausanne, Switzerland, and at TRL in Crowthorne, England. The scan team visited bridges, including the Nelson Mandela Bridge in Johannesburg, South Africa, bridges along the Swiss national roads, and the Oresund Bridge and tunnel linking Denmark and Sweden.

FOCUS

Topics for scan meetings were established in advance, and scan participants were asked to address these topics in their presentations. The topics are listed below:

- Organizational, policy, and administrative issues, including relationships among agencies (national, local), organization of bridge activities (design, construction, operations, inspection), inventory ownership and management, inventory characteristics (number, type, materials, span lengths), and inspection type, frequency, and rigor.
- Status of bridge management systems (BMS), including economic modeling and forecasting, deterioration modeling, and information technology (databases, architecture, input, data transfer, updating).
- Inspection issues and practices, including typical practices, innovative methods, use of nondestructive evaluation technologies, use of load testing, design for inspection (e.g., accessibility), and “smart” bridges.
- Operations issues and practices, including permit vehicles, load rating and load posting, indicators of performance and their relationship to design and other activities, maintenance, repair, and enforcement.

FINDINGS

A list of notable items from meetings was assembled as the scan proceeded. After meetings at each venue, the team compared notes and identified items with potential to improve U.S. practice. In all, about 100 items were added to the list. Similar items were collected into a list of 24 findings, and the findings were collected into 16 recommendations for further work. The findings are in Chapter Three.

THIS REPORT

This report provides a synopsis of findings, a set of recommendations for future work, and a review of the presentations to the scan team. The synopsis and recommendations appear in the Executive Summary. A review of presentations, organized by country, appears in Chapter Two.

Chapter Two
SYNOPSIS OF PRESENTATIONS

DENMARK

Administration

The Danish Road Directorate administers 1,618 kilometers (km) (1,005 miles (mi)) of trunk roads, about 2 percent of the total public road network in Denmark. Of these 1,618 km, 900 km (560 mi) are motorways, 150 km (90 mi) are highways, and 568 km (53 mi) are other trunk roads. In addition, Denmark has 498 km (309 mi) of connecting roads and exits for motorways and highways. The directorate is responsible for structures that include bridges, tunnels, retaining walls, noise barriers, signs, ferry berths, etc.

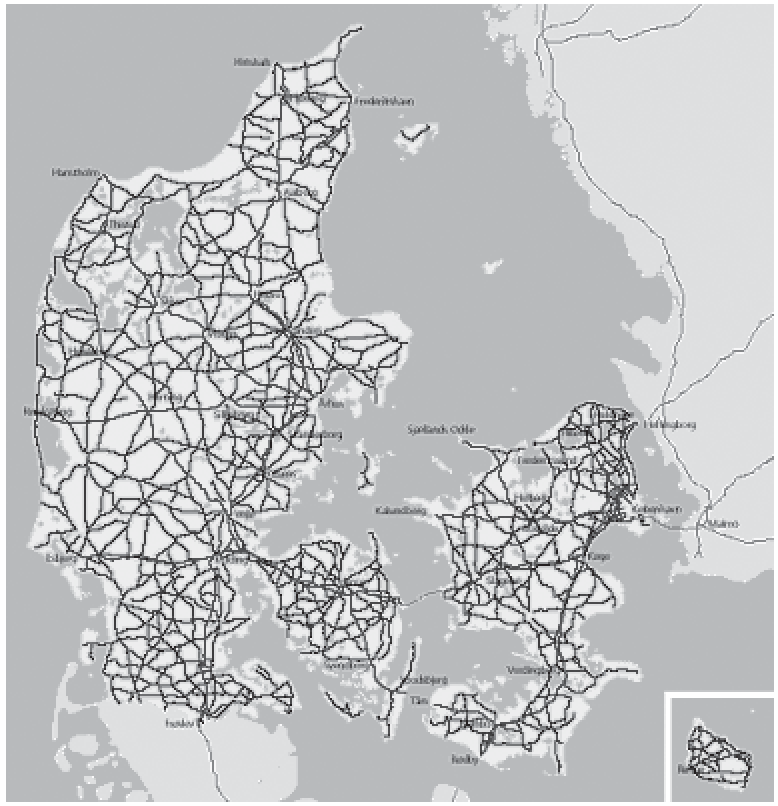


Figure 1. Danish trunk roads. (Road Directorate 2001)

Denmark has national, regional, and local roads, and three corresponding levels of roads agencies. Some roads and major bridges are conceded. Some crossings, including the Great Belt and the Oresund, are private roads.

The directorate has 420 employees, 70 of whom deal with bridges. The directorate spent DKr192 million (US$28 million) on maintenance and repair work on structures in 2000, about 80 percent of the amount needed to maintain current network conditions. The backlog of repairs on structures amounts to DKr500 million (US$73 million).

The directorate is responsible for planning, creating standards for design and construction, and inspecting structures. Engineering designs are prepared by consultants.

Bridge Inventory

In Denmark, a structure is a bridge if it has a span of at least 2 meters (m). It is a major bridge if it has a span of at least 200 m. Danish national roads have 1,315 bridges with a replacement value of DKr10.2 billion (US$1.5 billion). The bridge population is 43 percent post-tensioned concrete, 4 percent prestressed concrete, 26 percent reinforced concrete, and 25 percent steel-concrete composite. More than 85 percent of bridge deck area has bitumen overlay and membrane waterproofing. Many Danish bridges were built in the 1960s and 1970s.

Bridge Management System

The Danish bridge management system (BMS), DANBRO, manages bridges. DANBRO stores registration (inventory) data, engineering drawings, reports, and inspection data. The system began operation in the 1980s, and its development since then is part of a move to have all records, reports, and data electronically stored.

DANBRO stores digital photos used for bridge registry (inventory) data, but does not store photos from bridge inspections.

Most paper documents for bridges, including as-built plans, are scanned, stored as PDF documents, and linked to the DANBRO bridge database. The documents database is not accessible online. In future expansions, the database will include quantitative measures of deterioration, such as information on chloride ion content, corrosion, ASR, frost damage, etc.

A related system, DANBRO+, offers maintenance management for special structures, such as movable bridges, major crossings, and tunnels. These structures may have lift mechanisms, traffic signals, navigation lights, ventilation, control rooms for traffic operations, related buildings, communications nets, surveillance cameras, and other sensors. All of these require special knowledge for their operation, evaluation, and upkeep. DANBRO+ provides operating procedures, maintenance guides, and maintenance logs.

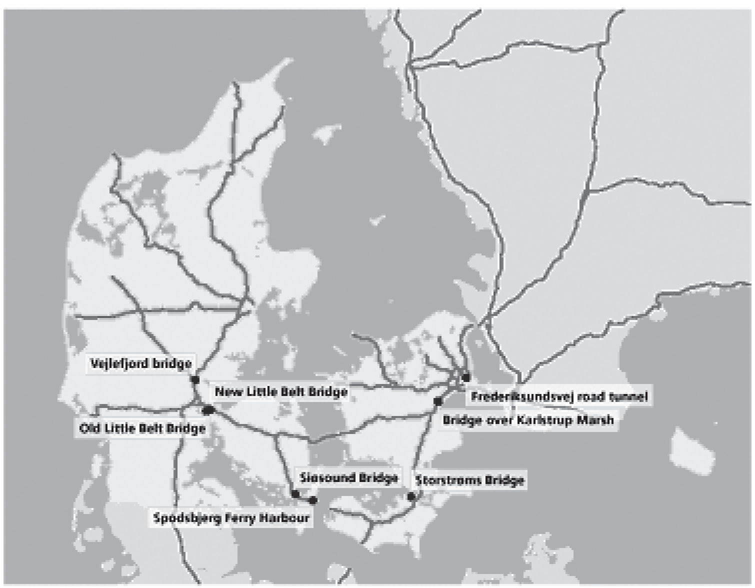


Figure 2. Major bridges needing urgent repair. (Road Directorate 2001)

Element/Condition Data

DANBRO recognizes 15 main components of bridges. For each component, inspectors can report conditions and recommend actions. Each component supports a deterioration model.

Bridges conditions are reported using a 0-to-5 scale, where 0 is perfect and 5 is worthless.

Data

All data entry is performed at the Danish Road Directorate. New data or modifications to existing data are verified by regional offices, and updated at the central office.

Priority/Maintenance Programming

Prioritization is a process of examining the tradeoffs between agency costs (related to construction) and traffic costs (related to delays). A matrix of alternatives is considered. Two project strategies are developed, one yielding minimum agency costs and a second yielding minimum traffic costs. For each strategy, projects costs are computed for immediate implementation, a delay of 1 year, a delay of 2 years, etc. Among these alternatives, maintenance program development seeks the best strategy and the optimal year of implementation. This planning exercise has a 10-year horizon.

Final programs are developed from the coordination of projects for roads and structures in a region.

Bridge Inspection

Types

Denmark has three types of routine inspection, daily, semiannual, and principal. Each day, the highway road patrol performs a driving inspection of all sections of the national roads, noting distress in bridges, pavements, and all other road facilities. Twice a year, each bridge is visited by the highway road patrol and a cursory examination is made for significant new defects. Every 6 years (sometimes sooner) a principal inspection of each bridge is conducted. Special inspections and monitoring programs are conducted at bridges as needed. Special inspections are performed to determine damage mechanisms and evaluate repair plans.

The principal inspection is an arms-length visual examination of all parts of a bridge. Each principal inspection produces reports of conditions and defects, and recommends the time to the next inspection. For each defect reported, the inspector will recommend a repair and its year of application, and will estimate the quantities and costs of the repair actions. The recommendation on the interval to the next inspection depends on the age, average daily traffic (ADT), location, existing conditions, and special features of the bridge.

Inspection Technology

Field computers are not used during inspections. A pilot project using computers on a local area network for inspection in tunnels was completed with poor results. In the tunnel, the telecommunications signal was not reliable.

Inspector Training

The inspector work force includes both Danish Road Directorate employees and consultants. Consultants with expertise in the testing methods needed for a project usually do special inspections. Training is chiefly by mentoring. New inspectors work alongside experienced inspectors to acquire skills.

Field Testing and NDT

Nondestructive testing (NDT) diagnostic methods are used for some bridges. The Danish Road Directorate has used corrosion rate measurements, impact-echo technique, radiography, ultrasonic pulse echo, and Raleigh wave measurements.

NDT use is not routine, and neither NDT raw data nor NDT-interpreted findings are stored in the bridge database.

Invasive inspections are sometimes performed on decks. A window of about 0.8 m by 0.8 m is opened by removing the wearing course and the waterproofing membrane so the condition of the surface of the structural concrete deck can be examined. Further excavation to view rebars, or removal of cores may also be performed.

Long-Term Monitoring

Permanent monitoring is used for selected, severely deteriorated bridges and for critical bridges. A monitoring program may include strain and deflections, crack widths, moisture content, pH, corrosion rate, chloride content, temperature, etc. Usually an automated onsite data acquisition system is installed. Data can be downloaded remotely via a modem connection and an Internet browser.

An example of a structure undergoing long-term monitoring is the Skovdiget Bridge, a viaduct that began cracking. Danish engineers installed sensors for continuous monitoring of crack opening movements at 200 locations. The monitoring system will remain in use until the structure is replaced. Increasing crack opening size indicates a deteriorating structure, and potentially a loss of safety. Using continuous monitoring, the Danish Road Directorate can track deterioration and ensure safety of the structure. Officials hope that the bridge can achieve a service life of 10 or 12 more years.

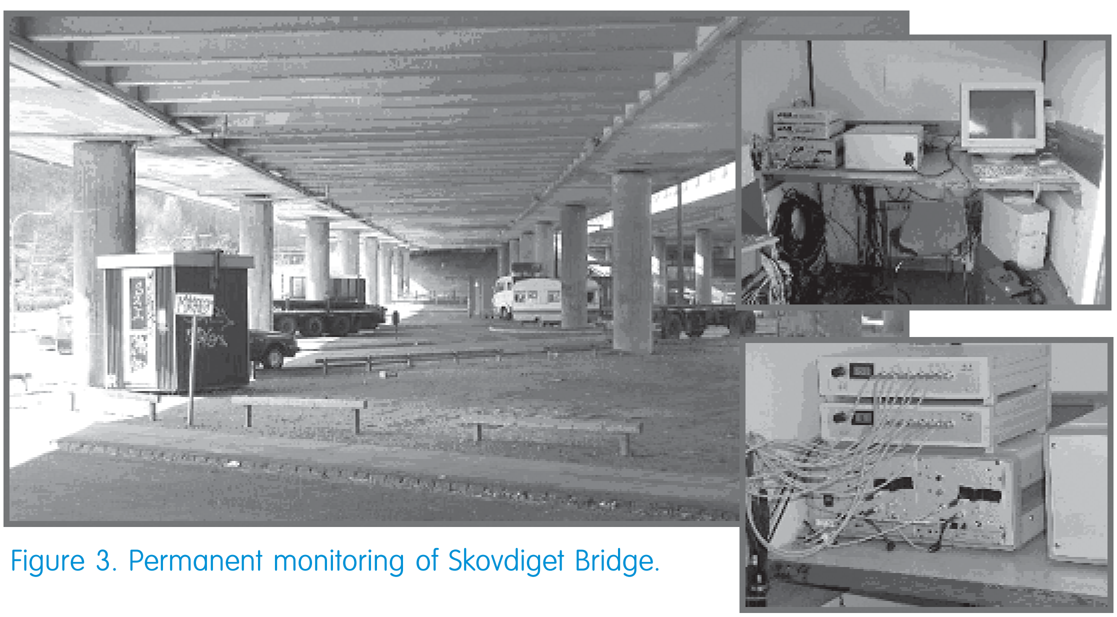


Figure 3. Permanent monitoring of Skovdiget Bridge.

Operations

Loads

Normal limits on axle loads are 10 metric tons (t) (22 kips) for domestic trucks and 11.5 t (25.3 kips) for international carriers. Geometric limits are width not greater than 2.55 m, height not greater than 4 m and length not greater than 18.5 m.

The normal truck gross weight is 40 t (88 kips). Higher loads require permits. Permits are routinely issued for loads up to 150 t (330 kips). Permits are issued through the Danish Police.

The Danish Road Directorate provides maps showing permissible maximum loads along routes. Maps are accessible over the Internet. “Blue” route bridges can take trucks greater than 100 t (220 kips). “Red” route bridges take trucks less than 100 t. The heaviest vehicles must cross bridges singly and must limit their speed to 10 km/h (6 mi/h).

Maintenance

The Danish Road Directorate defines maintenance as a foreseen action to maintain original condition. Maintenance for bridges is similar to oil changes for motors: It is done on a schedule, it is routine, and it is known to preserve the asset, yet it produces no visible improvement. Maintenance includes patch painting, clearing and grubbing, crack sealing, timber surface treatments, cleaning by hosing or sweeping, and renewal of guma (bitumen joints). Repair is the restoration of original condition in response to deterioration. Repair is a common action, but not an action on a regular schedule. Renovation (rehabilitation) is the improvement of a structure to higher load capacity or higher geometric standards in addition to repairs.

The 2003 roadway maintenance budget totaled DKr534 million (US$78.4 million), DKr195 million (US$28.7 million) of which was for bridges. Maintenance of walls and barrier maintenance is included in the budget for bridges.

Findings in Denmark

BMS

Road structures management. Denmark has a structures management system that includes bridges, culverts, ferry berths, noise barriers, retaining walls, sign structures, and tunnels**.**

Special structures. Denmark employs management systems for special structures that address all mechanical and electrical systems in addition to the structure itself.

Maintenance network programming. Maintenance programming at the network level entails studying agency and user costs for projects, computing variations in costs in response to scheduling of projects, and coordinating bridge and roads projects in a region.

Maintenance project planning. The Danish bridge management system, DanBro, requires that inspectors name the actions needed at structures.

Inspection

Inspection intervals. The Danish Road Directorate has three inspection types. Cursory inspections include daily and semiannual inspections. Principal inspections usually occur every 6 years.

Millions of crowns	Accounts 2000 price levels	Budget in accordance with National Budget 2001 2001 price levels	Budget in accordance with National Budget 2002 2002 price levels		
	2000	**2001**	**2002**	**2003**	**2004**
Administration etc,	97.6	98.7	98.5	95.4	93.6
Road sector operations	81.2	75.2	73.4	70.0	67.4
Total construction	948.0	764.6	959.9	1241.5	1249.7
- planning and management	28.2	32.3	46.1	33.6	29.9
- motorways. motor traffic roads	618.2	587.7	789.5	1067.7	1058.6
- other major national roads	156.2	-	-	-	-
- premature purchases of land	7.5	3.0	-	-	-
- completion works	-	4.7	3.3	2.4	2.4
- available funding	121.1	116.4	101.0	137.8	158.8
- replacement of cable crash barriers	16.8	20.5	20.0	-	-
Total operations and maintenance	543.5	532.0	620.2	604.5	388.0
- routine repairs nd maintenance	121.9	109.4	113.5	110.0	100.0
- winter maintenance	54.4	72.5	72.5	72.5	72.5
- road surfacing	101.4	110.1	107.0	106.0	74.0
- constructions	191.8	175.0	261.6	250.4	82.0
- road signals	46.8	41.0	42.2	42.2	42.2
- other running costs	27.2	24.0	23.4	23.4	17.3
Road user services	-41.0	-10.2	-14.2	-14.4	-14.4
Traffic management	22.0	27.9	28.3	27.6	27.5
Total	1,651.3	1,488.2	1,766.1	2,024.6	1,811.8

Figure 4. Budget detail. (Danish Road Directorate 2001)

Inspector mentoring. Training for Danish bridge inspectors is a hands-on, mentoring approach.

Nondestructive testing and field tests. Danish use of NDT and testing generally is similar to U.S. practice. Sampling, testing, and field installation of sensors are done when demanded as a diagnostic for a particular bridge.

Long-term monitoring. The Danish Road Directorate deploys permanent sensor arrays for close monitoring of deterioration so that bridges with known defects can remain in service with assured safety for users.

Maintenance

Washing. Washing of steel structures is a common routine maintenance activity. Danish practice focuses on removing debris and washing joint assembles.

Maintenance defined. For the Danish Road Directorate, maintenance is a routine, planned activity executed at set intervals. Repairs occur as needed in response to visible defects. Renovation is the improvement of a structure to higher design standards.

Reference: Danish Road Directorate, *The State of the Road Network* (2001), Report Number 234, 60 pp.

FINLAND

Administration

Finland has a road and rail network of 78,000 km (48,400 mi) that includes about 20,000 bridges. Total area of bridge decks is 3.4 million m^2 (36.6 million ft^2) and total length is 335 km (208 mi). Capital value of the bridge stock is EUR3,000 million (US$3.27 billion).

The Finnish Road Administration (Finnra) oversees contract work for construction, maintenance, and research. Finnra develops technical guides and standards, offers expert guidance to regional and local road agencies, and addresses all issues that must be coordinated at the national level.

Design, construction, maintenance, and most inspections are executed by contractors. Finnra's central office in Helsinki employs 250 people. Finnra's nine regional offices have a combined workforce of 750 people. In the recent past, Finnra was an operating agency. In 1988, Finnra had a workforce of 20,000 and performed many engineering functions in-house.

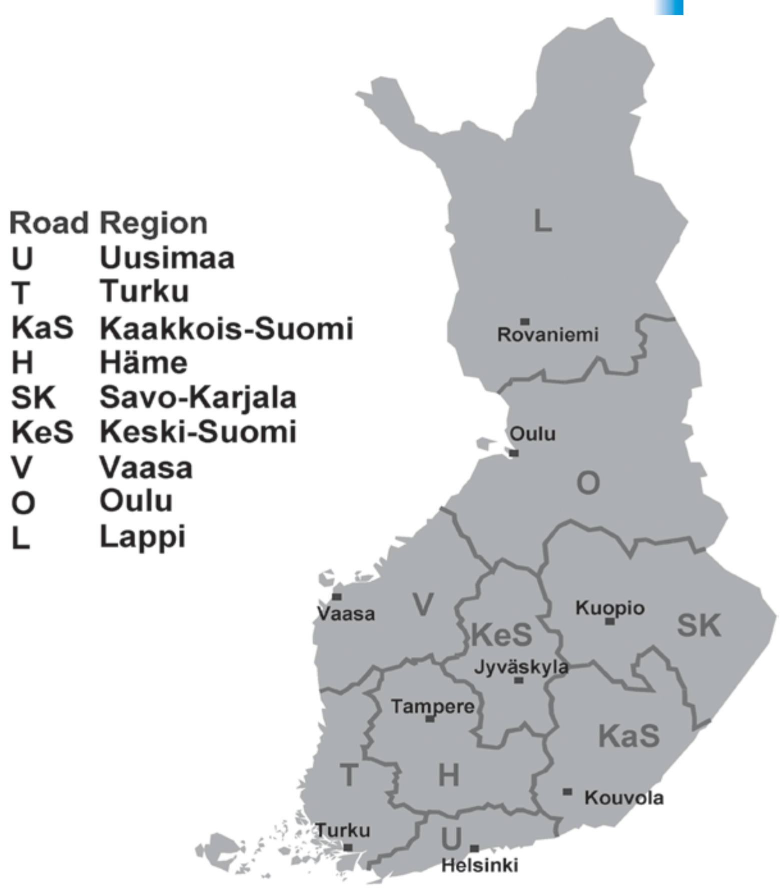


Figure 5. Finnra regions.

Bridge Inventory

In Finland, a structure is a bridge if its span is at least 2 m (6.6 ft). Finnra is responsible for 11,000 bridges. Many of these bridges were constructed in the 1960s and 1970s. Most bridges are reinforced or prestressed concrete. Steel-concrete composite beam bridges are used at many water crossings. A few bridges are timber or stone construction. Table 8 shows the distribution of bridges by deck area. The longest single span in Finland is 250 m (805 ft). Table 9 shows long-span bridges in Finland.

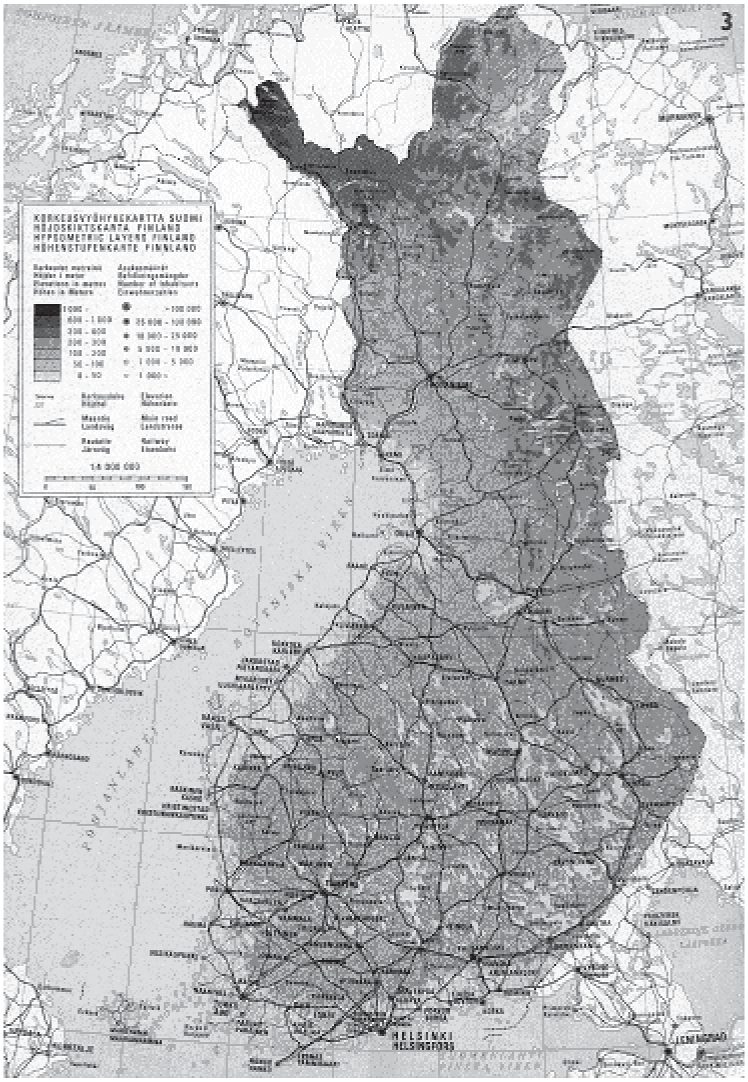


Figure 6. Finland's roadway network.

Table 7. Bridges in Finland.

Number	Type	Owner
11,000	Public road bridges	Finnish Road Administration
2,200	Railroad bridges	Finnish Rail Administration
1,800	Street bridges	Municipalities
2,400	Private bridges	Corporations
2,600	Private bridges	Private road owners

Table 8. Finnish bridge construction material.

Bridge Material	Population
Reinforced Concrete	60%
Prestressed Concrete	18%
Steel	19%
Timber	2%
Stone	1%

Table 9. Long-span bridges in Finland.

Bridge	Length/span/area (m/m/m2)	Year built
Raippaluodon silta, Mustasaari	1,045/250/12,540	1997
Tähtiniemen silta, Heinola	925/165/20,929	1993
Kärkisten silta, Korpilahti	788/240/9,456	1997
Saimaan silta, Puumala	781/140/10,153	1995
Lapinlahden silta, Helsinki	597/125/10,202	1965
Mansikkakosken silta, Imatra	557/75/12,874	1973
Suvantokadun silta, Joensuu	542/50/7,581	1974
Tervolan silta, Tervola	494/72/4,813	1975
Kirjavanjärven silta, Vihti	481/18/5,293	1976
Kaitaisten silta, Taivassalo	477/90/4,078	1982

The funding horizon for the bridge program is five years. The backlog of repair work is some EUR800 million (US$872 million). Bridge design intends a 100-year service life, during which the bridge is expected to require two rehabilitations. The budget for bridges is EUR50 million a year (US$54.5 million). Bridge conditions are reported on a 0-to-4 rating scale, with 0 being the best condition. Average condition in the network was about 1 in 1990 and declined to about 1.3 by 2002.

Bridge Management System

Finland's bridge management system began as an inventory system. Additional functions to evaluate repair needs, prioritize projects, estimate budget needs, and forecast future trends were added in the 1990s. These functions, in turn, have required an evolution in data, especially in the representation of bridges as elements and quantities, and in the relation of condition data to maintenance and repair actions. Today, inventory data are stored in the Finnra bridge registry, an Oracle® database. Bridge management employs two systems. HiBris (Highway and Bridge System) performs network-level management functions. Hanke-Siha performs project-level functions.

Finnra's registry includes vehicle bridges, pedestrian bridges, and culverts. The bridge population is composed of bridges on public roads, Finnra's culverts, Finnra's pedestrian bridges, bridges on transit roads owned by communities, bridges on other roads and streets maintained by Finnra, national heritage bridges, bridges on private roads subsidized by the state, abolished bridges, and adopted bridges. Community-owned bridges are coming in slowly.

Registry data exists in several categories: bridge basic data, load data, inspection data, and bridge repair data. Fields within each category include the following:

- Bridge basic data—Owner, use, road and traffic, structural, bridge equipment, and facilities data.
- Load data—Design load, load for legal normal vehicles, load carrying class, and load for special heavy transport.
- Inspection data—Damage data and damage cause, damage location, damage effect on bridge load capacity, urgency of repair measures, bridge overall

condition rating, bridge condition ratings for main structural parts, and research data.

- Bridge repair data—Recommended repair measures and costs.

Finnra's bridge registry produces a set of standard reports, including reports on basic bridge data, functional deficiencies, inspections, condition, repair work, and load-carrying capacity.

Finnra's bridge registry is linked to a database of images of bridges. Categories for images include the following:

- General photographs of bridge
- Photos of bridge details
- Photos of damage on bridges
- Construction photos
- Aerial photos
- Other photos
- General drawings of bridges
- Pictures of "bridge cards" containing small drawings of bridges and essential bridge data

By March 2003, the database had 37,000 photographs of more than 7,000 bridges. Additional photographs are added with each new bridge inspection (10,000 to 20,000 additional photographs each year). Photographs are stored as JPEG files. Image size is 768 by 1,024 pixels or larger, and average file size is 300 kilobytes. Photographs are not accessed from bridge sites during fieldwork, since limited bandwidth makes for slow transmission of images.

Finnra's management system, HiBris, instantiates a concept of joint optimization of road and bridge projects. HiBris as a single system replaces two older systems, HIPS (pavement management) and Verkko-Siha (network-level bridge management). HiBris uses Lindo optimization software, and operates on databases for roads and structures (the databases remain separate). Lindo (www.lindo.com) provides a suite of optimization routines, including simplex, linear optimization, and optimization with uncertainty in data.

Maintenance Priorities and Optimization.

Priorities for repair are based on two performance measures: KTI, a repair index, and UTI, a rehabilitation index. Optimization of maintenance programs depends on repair priorities, average daily traffic, costs, and forecasts of future costs and conditions obtained from deterioration models.

Optimization can operate on the entire Finnra network or on a subset network for a region or corridor. Finnra's practice is to collect homogeneous groups of bridges, and seek optimal maintenance programs for them.

Performance Measures

Finnra computes performance measures for defects, repair needs, and rehabilitation needs. A repair index is computed for the set of defects at a bridge. A rehabilitation index is computed for functional deficiencies. A repair index contributes to priorities for repair, unless the rehabilitation index indicates that a repair project should be set aside in favor of a rehabilitation project.

Defects in a bridge are assigned ratings in each of four categories: weight (importance in the load path, similar to South Africa's relevance indicator), condition of the structural part (apart from this defect), urgency of the repair (rate of growth of defect), and damage class (severity of the defect). For each bridge, a repair index, KTI, is computed for the set of defects, with the greatest weight placed on the worst defect.

$$KTI = \max(Wt_i \times C_i \times U_i \times D_i) + k\sum(Wt_j \times C_j \times U_j{}_{\times} D_j) \qquad \textbf{Eq. 1}$$

KTI = Repair index
Wt = Weight (importance) of the damaged structural part
C = Condition of the structural part
U = Urgency of the repair
D = Class (severity) of damage
k = A weighting factor for damage summation. The default value is 0.2
i = Worst defect
j = Other defects

Values for Wt, C, U, and D are shown in the following tables.

Table 10. Weight—Wt.

Bridge structural part	Wt
Substructure	0.70
Edge beam	0.20
Superstructure	1.00
Overlay	0.30
Other surface structure	0.50
Railings	0.40
Expansion joints	0.20
Other equipment	0.20
Bridge site	0.30

Table 11. Condition—C.

Condition Rating	Condition Points, C
0–New or like new	1
1–Good	2
2–Satisfactory	4
3–Poor	7
4–Very poor	11

Table 12. Repair urgency—U.

Repair Class	Repair Urgency Points, U
11–Repair during the next 2 years	10
12–Repair during the next 4 years	5
13–Repair in the future	1

Table 13. Damage class—D.

Damage Class	Damage Severity Points, D
1–Mild	1
2–Moderate	2
3–Serious	4
4–Very serious	7

KTI is further modified for average daily traffic (ADT). Factors for ADT are shown below.

Table 14. ADT factors.

ADT (vehicles/day)	Factor
> 6,000	1.15
3,000–6,000	1.10
1,500–3,000	1.00
350–1,500	0.90
<350	0.85

The rehabilitation and reconstruction index, UTI, combines deterioration, bridge load capacity, and functionality to determine whether a bridge should be rehabilitated or replaced rather than repaired.

$$UTI = kp \times kl \times (\text{Condition} + \text{Load Capacity} + \text{Functionality}) \quad \textbf{Eq. 2}$$

kp = Factor for bridge total area

kl = Factor for ADT

Finland sets annual goals for reducing severe deterioration in structures.

Bridge Inspection

Finnra has three types of routine inspections: annual, general, and basic. Finnra's general inspection occurs at intervals of 4 to 8 years. Five years is the usual interval. Finnra's basic inspection is a general inspection of a reference bridge or a large bridge.

Finnra's event-driven inspections include an acceptance inspection performed at the completion of construction or repair projects, and special inspections (special investigations) of structures to determine performance or to diagnose defects. Special inspections may include intensified monitoring. Monitoring may be by permanent sensors and data logging, or by frequent, simple visual examination.

Annual inspections are made by road foremen. General inspections are made by certified inspectors (an engineering degree is not required). Degreed engineers certified as inspectors perform basic inspections. Special inspections are performed by engineers with experience in the testing methods needed at the bridge. Underwater inspectors have special training. Intensified monitoring may require test specialists, certified inspectors, or road foremen, depending of the nature of the monitoring program.

The inspection budget is contained within the EUR50 million annual budget for repairs and renewal. General inspections are funded at about EUR500,000 a year (table 15).

Table 15. Finnra annual budget for inspection.

General inspections	Bridges under 60 meters long Steel culverts	EUR500,000	US$545,000
Special inspections	Larger bridges Cable-stayed, suspension, and movable bridges Bridges to be repaired, rehabilitated, or renewed	EUR450,000	US$491,000
Basic inspections	Reference bridges with analyses for age and behav-ior	EUR50,000	US$54,500

Inspector Training

Finnra's certification of inspectors requires a 4-day theoretical training course and 2 days of fieldwork followed by a field test. Certification requires annual advanced training. A separate 2-day course on the use of Finnra's bridge registry is required for inspectors who enter registry data.

During the advanced annual training, inspectors each complete general inspections of two bridges. Results among inspectors are compared and deviations are computed. Finnra sets limits on permissible deviation among inspectors, allowing larger deviation for evaluation of individual defects, and smaller deviations in the overall evaluation of a bridge. Repeated, large deviations can result in the loss of certification for an inspector.

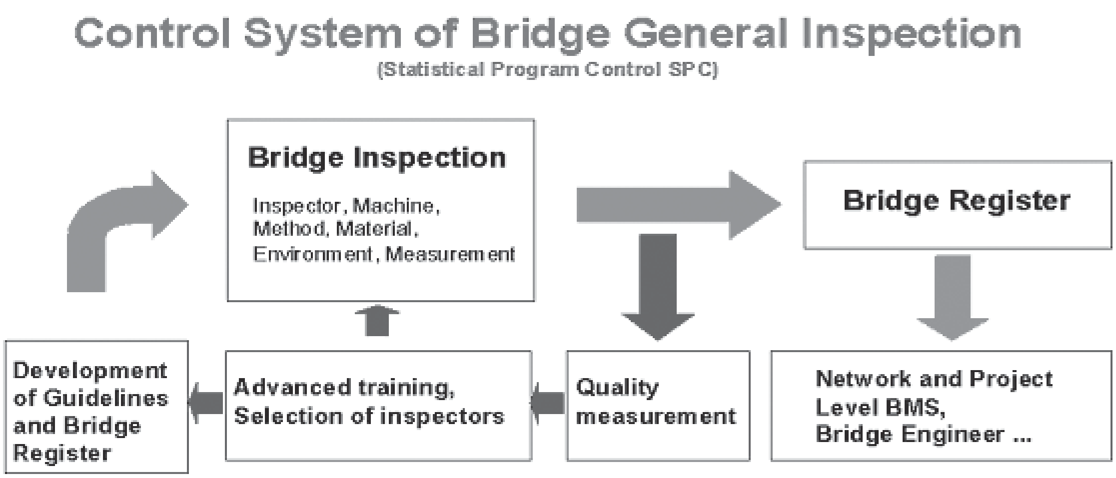


Figure 7. Finland's quality control for inspections and data.

Finnra Documents

Documents supporting bridge management include the Finnra *Guidelines and Policy for Bridge MR&R Operation*, *Guidelines for Bridge Inspection*, *Bridge Inspection Manual*, and *Bridge Repair Manual* (SILKO Guidelines).

Finnra's SILKO guides are notable. SILKO provides illustrated guides to most routine maintenance tasks. SILKO defines the defects to look for, method of measurement, recommended repair procedure and its step-by-step application, and the basis for acceptance of the work. SILKO is simultaneously a how-to manual and a specification.

SILKO has a central role in contract administration for conceded roads. SILKO provides the standard for adequate inspections, evaluation, and actions by maintenance contractors.

SILKO guidelines are available on the Web at www.tiehallinto.fi/sillat/silko/silko1.htm.

Field Computers

Data collected during bridge inspection are recorded on preprinted paper forms (reports generated from the Finnra bridge registry). The data can be entered to the database via a laptop computer and mobile phone or later at the office.

Global positioning system (GPS) data on bridges will be included in the bridge registry in the near future.

Field Testing and NDT

Field testing and sampling for lab analysis are routine activities for the set of reference bridges. Other NDT use occurs in special inspections of structures. In the future, Finnra may use modal analysis as an indicator of load capacity, acoustic emission for continuous surveillance of steel bridges, and automated methods for condition monitoring, including corrosion detection, moisture measurement, and monitoring of deflections.

Figure 8. Ultrasonic thickness inspection in Finland.

Long-Term Monitoring

Finnra is making its first trials of permanent monitoring at the Vihantasalmi Bridge. When it opened, Vihantasalmi was the world's largest road bridge with a timber superstructure. Sensors are deployed for temperature and moisture content in glulam members, and for displacements and deformations in the main members. The sensor array has wireless communication with the data logger.

Reference Bridges

Finland has a reference group of 106 bridges and 26 steel culverts. The behavior (performance) of the group is closely monitored to improve knowledge of bridge behavior and durability, and to calibrate BMS deterioration models. Reference bridges are used in training and annual recertification of bridge inspectors.

The reference group is subject to testing and sampling that includes the following:

- Carbonation depth of the concrete (phenolphthalein indicator)
- Acid soluble chloride content (rapid chloride test)
- Concrete deck cover (Proceq® Profometer 4, www.proceq-usa.com)

- Thickness of coatings in railings and steel structures (Elcometer® 245F, www.elcometer.com)
- Concrete compressive strength (Schmidt hammer)
- Relative humidity of the concrete (continuous, onsite using Vaisala HMI sensor and data logger, www.vaisala.com)
- Rebar corrosion rate (electrical potential measure)
- Pore water pH.

Testing yields material properties that include the following:

- Porosity of concrete
- Water penetration resistance factor
- Capillary factor
- Concrete compressive strength
- Concrete density and dry density
- Carbonation depth

Concrete cores taken from bridges are partitioned for use in several tests.

Figure 9. Finland's Vihantasalmi Bridge.

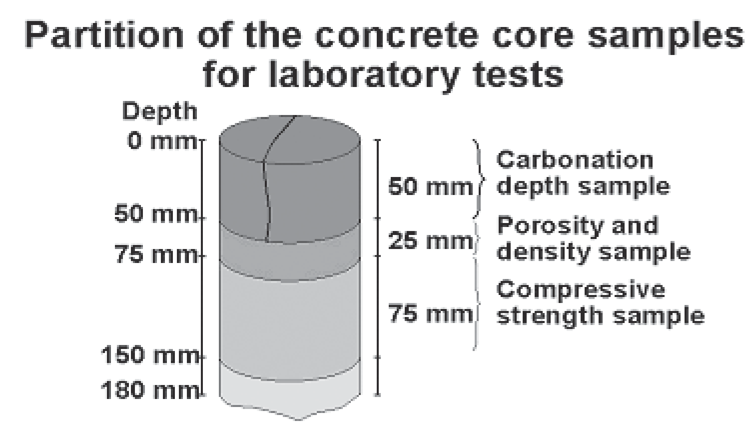


Figure 10. Partition of concrete core.

Data from the reference bridges are used to form general deterioration models for bridge elements, and specific models for freeze-thaw weathering and corrosion of reinforcing steel. Separate sets of deterioration models are formed for structures exposed to sea salts (seawater) or deicing salts, and for structures not exposed to salts. These models can be used for other Finnra bridges. Models can be adjusted at other bridges on the basis of material properties and environmental information. These adjustments are possible only with the detailed information obtained from the reference population.

An article on reference bridges that appeared in Finnra's newsletter is in Appendix B.

Operations

Loads

Design traffic loading is a combination of (truck) axle loads and a distributed loading. Lane width is 3 m (9.8 ft). The basic load case for design is the simultaneous application of 3 kilopascals (kPa) (63 pounds per square foot (PSF)) lane loading and a vehicle with three axles each bearing 210 kilonewtons (kN) (45 kips). This truck is 8.5 m (28 ft) long.

Load case 2 is a single axle weighing 260 kN (59 kips).

Permit Loads—Evaluation

Load ratings for bridges are performed for a catalog of vehicles differing in axle count and spacing. In each pattern, the axle weight "X" is determined for the bridge capacity limit. Routing for permit loads is prepared by Eriku, a software tool launched in 1993. The Eriku database represents the road network as a set of segments. For each segment, the database contains the load ratings for bridges and the clearances at bridges, tunnels, sign supports, etc. The Eriku algorithm identifies permissible routes and optimal routes. The user can constrain the route to contain or omit particular road segments. About 20 Finnra staff use Eriku software to issue transport permits.

Finnra identifies a network of national routes for large transports. These routes admit vehicles up to a height of 7 m and a width of 7 m (22.5 ft). The transport company bears all costs for sign removal, traffic control, and other work necessary for transport of the load. Also, the transport company is liable for any damage sustained by bridges or other structures.

Finnra issues permits for unsupervised travel by trucks weighing not more than 600 kN (135 kips), with a maximum axle load of 115 kN (26 kips), height not more than 4.2 m (13.5 ft) and width not more than 2.5 m (8 ft). Heavier or larger vehicles require a permit for supervised (escorted) travel.

A supervised overload receives a routing from Eriku. The load must be nondivisible. At each bridge, the supervised overload must travel at the centerline of the bridge and all other traffic is excluded. Limits on vehicle weights are enforced by police using movable scales. In the future, Finnra plans to use WIM for enforcement of vehicle weights and overload permits.

Permits cost EUR100 (US$109) for unsupervised loads, and EUR400 (US$436) for supervised loads. Permit fees cover administrative costs. Permits for unsupervised loads can be issued for periods of several months.

Maintenance

Finnra defines actions as follows:

- Maintenance—Cleaning of the bridge and annual visual inspection.
- Upkeep—Small repair works without engineering design, usually following a SILKO guide.

- Rehabilitation—Repair works requiring engineering design.
- Improvement—Widening and strengthening.
- New construction—New bridges and replacements.

Finnra maintenance includes actions such as cleaning and painting. Upkeep includes patching, realigning railings, and other actions that do not require engineering design. Repairs that require engineering design are rehabilitation. Rehabilitations are actions that require engineering design. Rehabilitations do not increase the function of bridges. Improvements require engineering design and achieve an increase in function. Replacements are just that—a renewal of a crossing, perhaps with an increase in function, achieved by removal and replacement of an existing bridge.

Findings in Finland

BMS

Maintenance management. The Finnra management system includes bridges, culverts, and pavements on bridges. The network-level system handles pavements and bridges (Hibris system).

Reference bridges. Finnra tracks a group of bridges as a reference set. These bridges allow Finnra to calibrate deterioration models, train inspectors, track long-term performance, quantify the effects of environmental conditions, and evaluate testing techniques.

Corridor management. Finnra's HiBris management system generates maintenance programs optimized simultaneously for both bridges and pavements. Optimization can be performed for the entire network, or for a subset of the network in a region, along a route, or for a set of similar structures.

Inspection

Inspection frequency and type. Cursory inspections are performed by road maintenance foremen once a year. General inspections are performed at 4-to-8-year intervals. Five years is the usual interval.

Inspection annual certification. Finnra conducts an annual workshop for bridge inspectors. As a part of this, inspectors evaluate bridges independently and their results are compared. Inspectors must achieve results consistent with their peers to retain certification

NDT and field testing. Testing and sampling are used extensively in basic inspections for the reference group of bridges. At other bridges, NDT use is much like U.S. practice.

Monitoring. Finnra is experimenting with permanent sensor systems to track conditions at bridges.

Maintenance

SILKO. Standard procedures for inspection, assessment, and repairs are presented in the Finnra SILKO guides. These are terse, illustrated guides to most routine maintenance tasks. SILKO also has a central role in contract administration for conceded roads. SILKO provides the standard for adequate actions and oversight by maintenance contractors.

Operations

Permit load routing. Finnra employs a software tool, Eriku, to generate routes for permit loads.

FRANCE

Administration

Road authorities exist at three levels: national (state level), departmental, and local (cities, towns, and villages). The French National Road Directorate, an agency in the French Ministry of Equipment[1], provides funding to national road agencies acting in the departments, and establishes national policies for road transport. The directorate also develops and operates the bridge management system. Departmental agencies (DDE)[2] perform repairs of bridges, and conduct specialized studies or investigations as needed. Local agencies, called subdivisions, each guided by a departmental agency, perform routine inspection and maintenance.

Road administration has been partly decentralized since 1982. The Ministry of Equipment controlled 105,000 bridges before decentralization. Today, the ministry directly controls only 23,000 bridges, and controls the activities of six companies that manage conceded motorways with another 7,000 bridges. This shift reflects a philosophy of decentralization and conceding of most activities. Working with the directorate are five general supervisors belonging to the General Bridge Inspection Service. Each supervisor is charged with a geographic region in France. General supervisors control DDE activities in the field of bridges.

National funding for bridge repairs is allocated to departmental road agencies through five general supervisors. Most actions (inspections, maintenance, repair, and replacement) are handled by departmental road agencies after review, approval, and funding by the national government.

Technical organizations involved in bridge engineering and road operations include the following:

- **SETRA** (Service d'Etudes Techniques des Routes et Autoroutes). SETRA reviews proposed repair projects and operates LAGORA, the French bridge management system.
- **CETE** (Centre d'Etudes Techniques de l'Equipement). CETE is a group of eight regional centers that provide technical advice to local roads agencies, and assist in bridge investigations and planning for repair projects.

- **LCPC** (Laboratoire Central des Ponts et Chaussées). LCPC, the central (national) laboratory, performs bridge research and provides expert technical advice on bridges.
- **LRPC** (Laboratoire Régional des Ponts et Chaussées). LRPC, a group of 17 regional laboratories, engages in detailed inspection, testing, instrumentation, and diagnosis for bridges and structures.
- **CETU** (Centre d'Etudes des Tunnels). CETU performs detailed inspection, testing, and studies of tunnels.

Bridge Inventory

In France, it is a bridge if the span is at least 2 m (6.6 ft). France has some 236,000 bridges. The French National Road Directorate administers only 23,000 of these directly, and another 7,000 bridges through maintenance concessions. Departments and local authorities control 85 percent of the bridges. The replacement value of bridges administered directly by the French National Road Directorate is EUR11 billion (US$12 billion).

Table 16. French bridge inventory.

Owner	Number of bridges
State (Road Directorate)	23,000
State (conceded motorways)	7,000
Departmental Authorities	85,000
Local Authorities (cities, towns)	115,000
SNCF (rails)	6,000
Total	236,000

Some 85 percent of the bridges managed by the French National Road Directorate have spans of less than 50 m, about 50 percent of the bridge deck area is on prestressed concrete bridges, and 60 percent of the bridges are less than 25 years old. Total bridge deck area is 8.4 million m^2 (90 million ft^2). Beyond bridges, the directorate administers 230 tunnels and covered trenches with a total length of 86 km (53 mi), and 14,000 retaining walls with a total length of 900 km (560 mi) and surface area of 3.2 million m^2 (34.4 million ft^2).

Bridge Management

France relies on the judgment of engineers to form and prioritize repair projects, estimate costs, and predict future conditions in the network. France does not use software to generate repair recommendations or program repairs, or deterioration models or other automated methods to forecast future maintenance needs. In France, the bridge management system keeps inventory information, data from inspections, and the repair projects and costs proposed by engineers. The system generates reports on the condition of the network, the backlog of repair projects, and the existing budget needs.

Bridge Inspection

France has four types of inspections: routine visit, annual inspection, IQOA[3] evaluation inspection, and detailed inspection. Routine visits are made by agents during their patrols. Annual inspections are cursory examinations intended to discover new, significant defects in structures and to program routine maintenance. IQOA evaluation inspections occur every 3 years and are more complete visual examinations of structures to classify the condition of bridges into IQOA classes. Detailed inspections occur every 6 years (in fact, the frequency now varies from 3 years for structures with problems to 9 years for robust structures) and are thorough visual examinations of bridges noting all defects. The detailed inspection is a de novo examination, while the annual examination is a check to verify conditions believed to exist at the structure

Detailed inspections are performed for retaining walls and tunnels. For walls, the inspection team must include at least one structural engineer and one geotechnical engineer.

Inspector Training

In France, the activities for inspection and development of repair projects are closely linked. Certifications for three technical grades—project manager, inspector, and inspection agent—arise from a common sequence of training courses (training modules, in French nomenclature). In addition to training, certification at each level has requirements for formal education and experience. Certification is awarded after examination and review by a qualifying board of agents of the Network of Roads and Bridges Laboratories.

Three levels of certification are recognized:

Project manager Establishes findings on the causes of defects in a bridge, proposes investigations and/or repair actions, and finalizes the inspection report.

Inspector Performs the inspection and drafts the inspection report, including a preliminary statement of findings.

Inspection agent Assists the inspector and the project manager.

Training modules are organized to provide instruction for the inspection of particular types of structures. The following are the first five modules:

Module 1 General structures including common forms of bridges in reinforced concrete, prestressed concrete, and masonry; culverts; and common retaining walls.

Module 2 Steel and steel-concrete composite structures.

Module 3 Prestressed concrete bridges with long spans and/or unusual forms.

Module 4 Cable-supported bridges.

Module 5 Uncommon retaining walls and underground structures.

A sixth module, intended for project managers, addresses methods for special inspections, investigation techniques, monitoring and surveillance techniques, repair and strengthening techniques, and project development after an inspection.

Departments establish requirements for inspector agents. Inspectors must have a degree in civil engineering and at least 2 years' experience with bridges, and must complete training module 1 on general structures. Inspectors may, and usually will, complete other training modules giving them a complementary certification. Indeed, the permissible practice area for an inspector is determined by the modules completed. Project managers must have a degree in civil engineering and at least 5 years' experience with bridges, and must complete modules 1, 2, 3, and 6. Often, individuals have completed all training modules by the time they become project managers. Inspectors and project managers alike are certified by an examining board after an inspection test in the field. Examining boards review candidates' work history, and conduct written examinations and interviews.

Inspection Guides and Standards

In France, the *Instruction Technique pour la Surveillance et l'Entretien des Ouvrages d'Art* (ITSEOA), last updated in 1995, establishes procedures for inspection of most roadway infrastructure, including bridges, tunnels, culverts, retaining walls, and embankments. The first part of ITSEOA addresses administration issues. The second part consists of 30 documents addressing methods and techniques for particular materials and structures. Condition assessment is further guided by the *Image de la Qualité des Ouvrages d'Art* (IQOA), which present the IQOA classification for each kind of deterioration and damage encountered on some 25 types of structures.

Condition ratings are reported on a 1-to-3 scale. The 2 and 3 ratings are subdivided according to the urgency of maintenance. Moreover, a special mention S is added to structures presenting safety problems. Many French bridges have conditions between 2E and 3U (table 17). Network conditions are shown in Table 18 and figure 11.

Table 17. French condition ratings.

Condition	Definition	Urgency
1	Good condition.	
2	Good condition or minor defects. Maintenance required.	Not urgent
2E	Minor defect requires prompt maintenance.	Urgent
3	Damaged structure. Repair needed.	Not urgent
3U	Damage requires prompt repair.	Urgent
NE	Not evaluated.	
Mention S	Condition endangering the safety of users.	Urgent

Table 18. Current network conditions.

Condition	%, based on bridge deck area
All Bridges	
2E to 3U	47%
3 and 3U	16%
Prestressed Concrete Bridges	
2E to 3U	53%
3 and 3U	19%

IQOA defines inventory data and condition data for retaining walls as well as bridges. Walls are defined as retaining features greater than 2 m high. Condition ratings for retaining walls are based on observed condition of the wall face, retained fill, drainage, and other equipment, such as barriers or railings mounted on the wall.

IQOA defines inventory data and condition data for tunnels. Tunnels are collected into three categories: tunnels with liners, unlined tunnels, and tunnels below water.

Field Testing and NDT

France employs a number of field-testing methods for evaluating bridge performance. Testing is not a common part of routine inspections, but these methods are widely used in France for investigation of structures, and widely understood by bridge engineers.

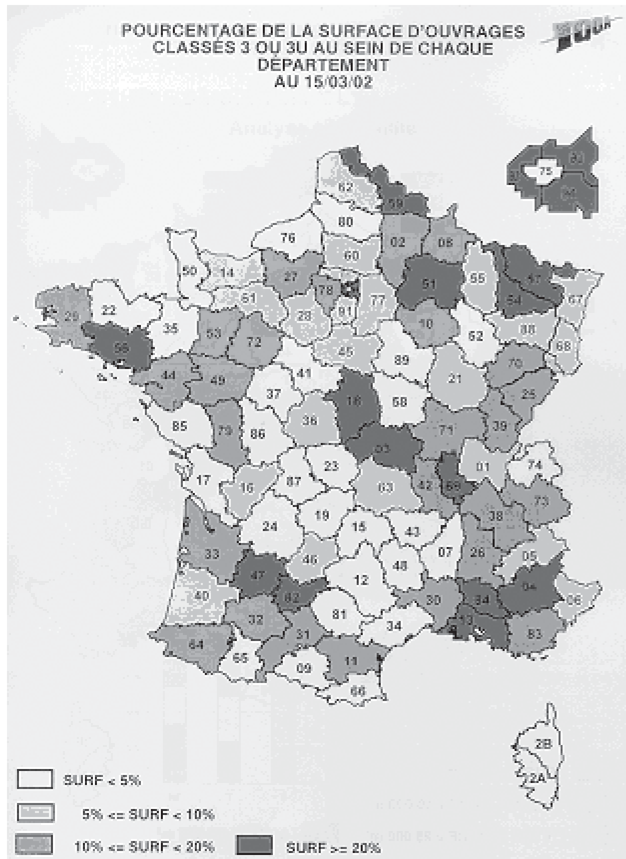


Figure 11. Distribution of condition ratings 3 and 3U based on bridge deck surface area.

- Gammagraphy—Radiographic imaging for internal condition of prestressing strands, including evaluation of grouting in post-tension ducts.
- Support reaction measurement—Unloading of support reaction by jacking to verify the distribution of forces in structures. For continuous spans, this is an evaluation of secondary moments.
- Crossbow method—Transverse jacking of exposed prestressing strand over a fixed gage length to determine tension force.
- Flat jacks—In situ determination of stress levels in concrete, masonry, or other massive elements.
- Decompression moment—A specialized load test with displacement measures at hinge, joint, or sometimes a crack. It provides an indirect measure of prestress force.

Further descriptions of French practice with NDT is provided as excerpts from Brigitte Mahut's presentation to the scan team.

Gammagraphy

Gammagraphy has been used since the 1970s for evaluating both bridges under construction and existing structures. Gammagraphy can reveal wire breaks and absence of grout at tendons, and can determine the location of strands and ducts before drilling into beams.

Support Reactions

Support reactions are measured by jacking, transferring the reaction force to a calibrated jack so reactive force can be inferred from pressure of the hydraulic fluid. In France, accuracy of 1 percent of reaction force at abutments and 0.1 percent at intermediate supports is reported. The method requires sufficient room for deploying the jack. Usually a height of 150 millimeters (6 inches) is needed. The jack must be mounted on a competent support point and engage the bridge superstructure at a permissible location. Support reaction values allow a verification of secondary moments in continuous, prestressed structures.

Cross-Bow

The crossbow method entails transverse loading of a prestressing wire or tendon. For internal tendons, the method is invasive but not destructive. The slope of the load/deflection curve is related to the tension force in the tendon.

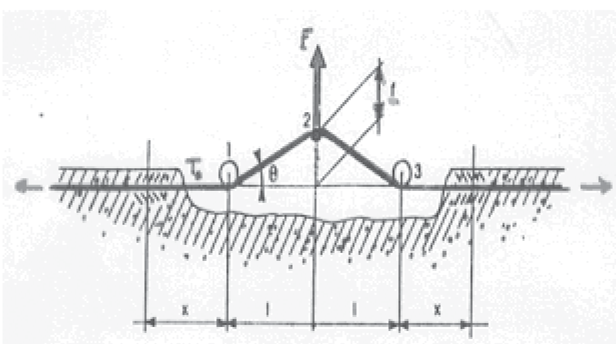


Figure 12. Crossbow method.

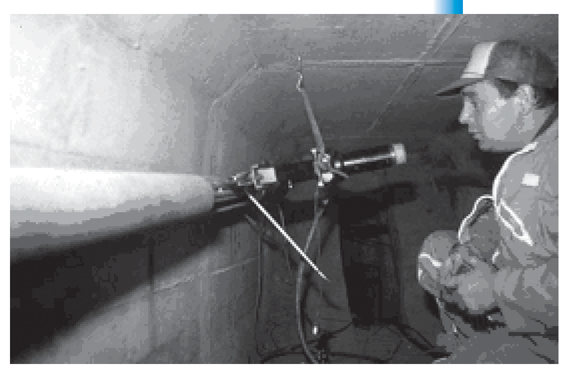


Figure 13. Crossbow method.

Flat Jacks

Flat jacks offer a direct indication of local stresses in concrete. The method is invasive, but not destructive. The flat jack is mounted in a shallow slot cut into the member. Accuracy is reported as better than 500 kPa (73 psi).

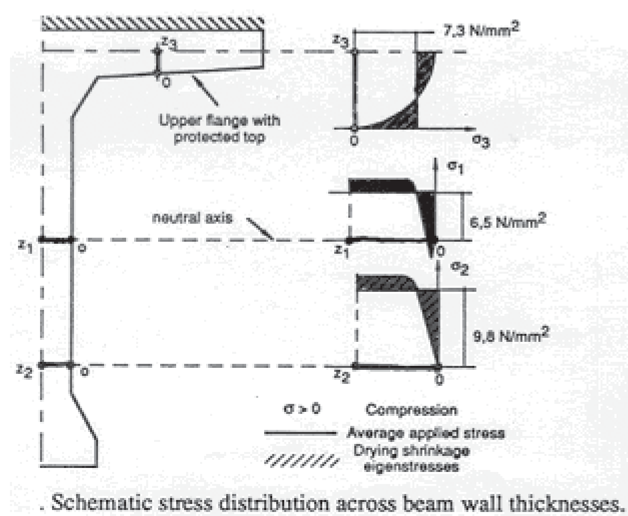


Figure 14. Flat jack use.

Decompression Moment

The decompression moment is reached when applied loads exceed the precompression imposed by prestressing strands. Beams are prepared with a set of strain transducers at one or more sections, with a sufficient number of transducers at each section to capture the strain profile. Load is applied using trucks, and moment is increased using more and/or heavier trucks until a nonlinear load/strain response is observed.

Additional NDT methods

- Impact-echo—LCPC is conducting research on the use of the impact-echo method to detect voids in concrete members, and the absence of grout in tendon ducts. Similar applications are used in the United States.
- Ground-penetrating radar—France is using radar, again at a research level, to detect and locate reinforcing steel bars in concrete members.

Monitoring

In France, intensified surveillance is the close monitoring of the evolution of damage in a defective or doubtful bridge. Monitoring is an exceptional activity for abnormal situations. Occasionally, intensified surveillance is used as part of a special investigation to diagnose the problem at a bridge or to better understand the behavior of a bridge. Intensified surveillance may also be used to verify that repair or strengthening actions are effective.

Intensified surveillance can have several forms: frequent and regular visits to the bridge for visual examination, periodic quantitative measures of damage by simple means or with instruments, or installation of sensors and data acquisition systems. Surveillance can continue over a year or more to discern the behavior of a structure through the seasonal weather cycle.

Safety monitoring is similar to intensified surveillance in execution. A safety-monitoring program is distinguished by its focus on a particular damage mechanism and specific potential failure of the bridge. Safety monitoring is the continuous, automated tracking of damage evolution.

Safety monitoring is appropriate when failure may occur if a known damage worsens, but can occur only if the damage worsens. Moreover, growth of the damage must be measured reliably by an instrumentation system, and the measurement must admit a simple interpretation of damage severity. Overall, the monitoring system must offer an assurance of safety.

The implementation of safety monitoring requires a preliminary five-stage analysis: analysis of the bridge condition, study of the various possible failure paths, choice of the failure path(s) with the greatest probability of occurring, selection of the measurable physical quantities that reveal an unfavorable evolution of damage in the bridge, and selection of thresholds of values of the physical quantity that will require emergency repairs, restrictions of loads, or bridge closure. Safety monitoring usually depends on automatic acquisition of measurements by sensors. Usually, sensors are combined with data acquisition and transmission capabilities, and the monitoring system can trigger an alarm for the road agency.

An example of safety monitoring is the Tancarville Bridge across the Seine. A suspension bridge with a main span of 608 m (1,995 ft), it was the longest suspended span in Europe when it was completed in 1959. The deck is continuous through the towers and is stiffened by two 6-m-deep steel trusses. Corrosion in the main suspension cables produced breakage in a few wires as early as 1965. Steel wires were not galvanized, and at low points wires were exposed to water spray from traffic. In winter, spray water often contained deicing salts. Corrosion continued to worsen, resulting in the breakage of an entire strand near the anchorage in 1995 and the decision to replace the main cables.

Cable replacement required 4 years, and the bridge was to remain in service during the project. To assure the safety of the bridge, an acoustic system was installed to monitor the continuing breakage of wires. The 1995 assessment of the remaining strength of the main cables, together with the quantitative measure of subsequent wire breaks, allowed engineers to assess the remaining strength of the old cables while new cables were installed.

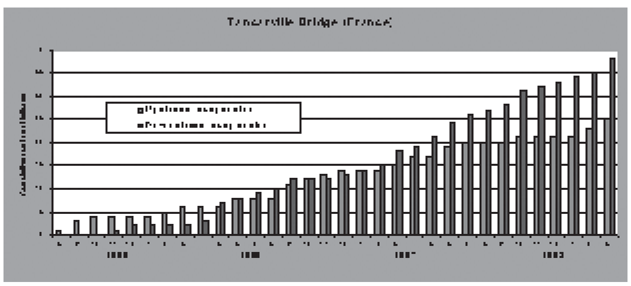


Figure 15. Acoustic monitoring of cumulative wire breaks.

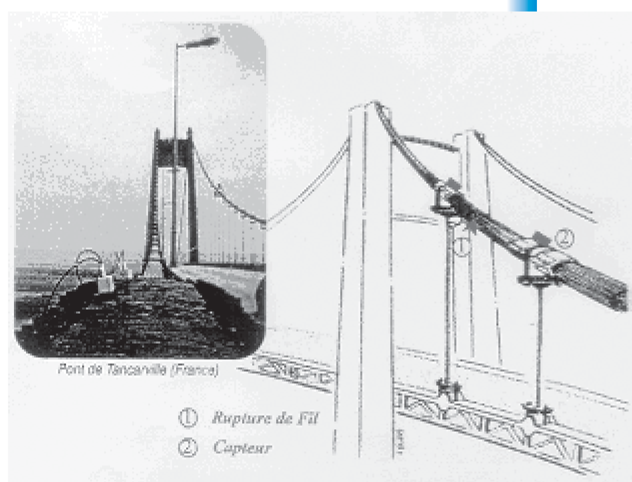


Figure 16. Acoustic monitoring at Tancarville Bridge.

Permit Loads—Routing and Automation

About 40 percent of the trucks on French roads have weight greater than the nominal 40 t (88 kips) standardized by the European Union. Abnormal loads are often as great as 60 t (132 kips). Transit of abnormal loads is arranged with road agencies in the departments.

Maintenance/Repair Guides

France maintains guides and standards for repair materials and methods for civil engineering structures. These publications are developed variously by LCPC, Association Française de Génie Civil (AFGC), and Association Française de Normalisation (ANFOR).

LCPC publications include the following:

- *Choix et Application des Produits de Reparation et de protection des Ouvrages en Beton*—A guide to selecting repair products for concrete structures.
- *Référentiel Pour Les Produits De Réparation—produits inscrits à la marque NF*—A guide to selecting certified repair products.
- *Mise En Peinture Des Bétons De Génie Civil*—A guide to concrete painting products addressing adhesion, coating thickness, and aesthetic qualities.
- *Protection des bétons par application de produits à la surface du parement* (December 2002)—A guide to selecting and applying surface coatings on concrete structures.

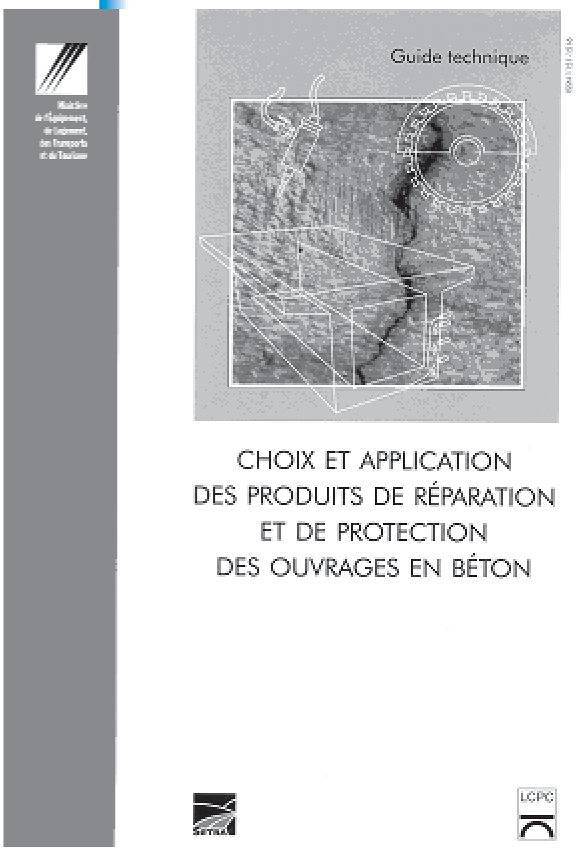


Figure 17. LCPC guide to repairing and strengthening concrete structures.

ANFOR certifies products used for repairs, and publishes technical advice on repairs and the use of repair products. ANFOR has developed publications on the following topics:

- Repair of superficially deteriorated concrete—NF P 95-101 (November 1993)
- Sprayed concrete—NF P 95-102 (June 1992, revised 2002)
- Repair of cracks and protection of concrete—NP P 95-103 (June 1993)
- Strengthening by additional prestressing—NF P 95-104 (December 1992)
- Repair of foundations—NF P 95-106 (August 1993)
- Repair of masonry—NP P 95-107 (August 1994, revised 2002)
- Hydraulic products for fixing and clamping—NP P 18-821
- Synthetic products for fixing and clamping—NF P 18-822
- Hydraulic or synthetic for surface repair—NF P 18 840
- Hydraulic or synthetic for structural gluing—NF P 18 870
- Hydraulic or synthetic for injection—NF P 18-880

ANFOR certification of protective products assures the effective protection against one or more of the following:

- Water penetration

- Chlorides penetration
- CO_2 penetration
- Internal swelling reactions (alkali-aggregate reaction)
- Ice/deicing
- Water pressure

ANFOR has established two classes of qualification, both good:

- Class 2—Highest class. Very efficient product for its intended function.
- Class 1—An efficient product.

Products are subject to a series of tests assessing their ability to protect against specific agents, and their qualities related to installation, maintenance, and appearance. The manner of application is addressed. The durability of products is evaluated for resistance to abrasion, tolerance of cracking (while continuing to offer protection), ease of maintenance by reapplication, and ease of spot repairs of a coating.

ANFOR guides are intended for bridge owners, consultants, and managers confronted with problems of durability of reinforced concrete. The products may be employed to preserve existing structures, enhance new structures, or offset known vulnerabilities in some structures, such as insufficient concrete cover.

ANFOR's Web address is www.afnor.fr/.

Publications by AFGC include the following topics:

- Repair with glued steel sheet—Technical guide AFGC/STRRES No. 6 (June 1987).
- Repair and strengthening of concrete structures using fiber-reinforced polymer (FRP) in AFGC's *Recommendations* to be published in 2003. The g will include characterization of FRP materials (carbon fibers, glass fibers), methods of calculati installation of FRP, and in situ control. France m its first bridge repair with carbon fiber material 1996.

Figure 18. Guide to concrete maintenance products.

Planning

In France, engineers select repair projects. No automated system for priority ranking or maintenance program development exists. Each departmental agency (DDE) creates a 3-year plan for bridge projects, identifying the bridges, repair actions, and estimated costs. These plans are reviewed by SETRA first, and then go to the regional general supervisor with SETRA's comments. The supervisor merges the departmental plans in the region, and creates a priority ranking for projects. From this merged list, funding allocations are determined. For routine projects, funding is allocated to the department and the project proceeds under department supervision. For large bridges or special, complex problems, a detailed project planning exercise, called a fore-project, is required. The fore-project entails special investigations of the bridge, estimates of the load capacity of the bridge and how capacity is affected by the proposed repairs, and an itemized estimation of costs. The report on the fore-project is reviewed by SETRA first, and then goes to the general supervisor. Once it is satisfactory, funds are allocated to the department and the project proceeds.

Each year, SETRA reviews about 500 routine projects and 30 fore-projects.

Priorities for repair consider the strategic importance of the bridge and the urgency of the repair to assure safety. In addition, supervisors seek an even distribution of projects among departments. Also, political aspects of decisions are considered.

Budgets

The annual budget for surveillance and routine maintenance is EUR12 million (US$13 million). This is allocated to department road agencies as EUR1.4 m^2 (US$0.14 ft^2) of bridge deck. Rehabilitation has an annual budget of EUR60 million (US$65 million). This is the budget allocated by the five general supervisors. The maintenance budget is about 0.68 percent of the replacement value.

Table 19. Annual budgets for bridges and tunnels.

Detailed inspections, studies, repair projects	EUR12 M	US$13.2 M
Routine maintenance	EUR23 M	US$25.2 M
Repairs and strengthening	EUR65 M	US$75.9 M
Replacement value of the stock	EUR15,245 M	US$16,770.0 M
Cost of maintenance/replacement value	0.68 %	

The backlog of bridge rehabilitation projects in France amounts to EUR1,060 M (US$1.2 billion), about 18 times the annual budget for strengthening

Findings in France

Administration

Decentralization. Most bridges are administered by departmental or local authorities. Funding for bridge repair projects on the national road network involves departmental agencies, SETRA (national), CETU (national), and general supervisors.

BMS

Maintenance management systems. The French maintenance management system, LAGORA, includes bridges, culverts, and retaining walls. Tunnels are managed by CETU.

Deterioration models. LCPC is conducting research on quantitative bases for deterioration models for concrete bridge members. These models are linked to the physical description of carbonation and chloride ion contamination, and alkali-aggregate reaction. Deterioration models are not used in maintenance planning.

Inspection

Inspector training. France offers training modules addressing different kinds of bridge structure. The levels of certification from agent to inspector to project manager (one who recommends repair projects) require increasing levels of experience, completion of increasing numbers and levels of inspection training modules, and examinations by committee. This certification process is only available among the network of regional laboratories.

Testing methods. France makes frequent use of field tests to verify bridge conditions. Many tests are directed at verification of prestress levels. The crossbow test, a measured lateral force deflecting a prestressing strand or wire over a fixed gage length, provides a direct measure of prestress tension. Flat jacks offer direct measures of stress levels in concrete members. Decompression moment is a controlled load test method that yields the moment necessary to offset precompressions in concrete members. Support jacking offers a verification of secondary moments in statically indeterminate bridges, which also yields an estimate of prestress force.

Maintenance

Repair Manual. France maintains a manual of repair procedures for concrete structures. Materials for concrete repair are certified annually by ANFOR.

GERMANY

Administration

National roads are administered by the Bundesministerium für Verkehr, Bau- und, Whonungswesen (Federal Ministry of Transport, Building, and Housing (BMVBW)). The ministry provides advice and technical support to states and to other federal agencies. States administer inspections, control structural data in the BMS, and develop 5-year plans for maintenance programs.

The Bundesanstalt für Straßenwesen (BASt) is Germany's Federal Highway Research Institute. BASt was organized in 1951 to support road construction. This mandate was expanded in 1965 to include traffic operations and again in 1970 to include traffic accident

Figure 19. German states.

research. BASt has a staff of 400 and an annual budget of EUR35 million (US$38 million).

Tax revenues support the road network, but funding is discretionary. No dedicated funding, such as a percentage of a motor fuels tax, exists.

Bridge Inventory

Table 20. German roads and bridges.

Overall road network	626,000 km
Federal Highways	11,800 km
Federal Trunk Roads	41,200 km
Federal Roads	35,963 bridges
Highways	15,785 bridges
Trunk Roads	20,178 bridges

Germany has a roadway network of 626,000 km (389,000 mi). Federal highways total 11,800 km (73,00 mi), and other trunk roads total 41,200 km (25,600 mi). The balance of the network is made up of state highways and local roads. In Germany, it is a bridge if its span is at least 2 m (6.6 ft). Germany has 35,963 bridges on federal roads, 20,178 bridges on trunk roads, and 15,875 bridges on highways. Most German bridges were constructed in the 1960s and 1970s. German engineering practice seeks designs that are effective in a number of aspects, including constructibility, maintainability, and inspectability.

The replacement value of bridges is EUR4.5 billion (US$4.9 billion). Deck area is 25.55 million m^2 (275 million ft^2). Most bridge spans are less than 50 m (164 ft). Germany has 200 bridges with spans greater than 500 m (1,640 ft).

Deterioration in German bridges is due to carbonation, chloride ingress, alkali-silica reaction, inadequate waterproofing and surface drainage, inadequate concrete cover, inadequate injection grouting, and inadequate freezing resistance. Post-tensioning tendons can have fatigue problems at coupling elements, and corrosion cracking in older steel tendons. Germany has some 800 bridges with vulnerabilities related to fatigue in couplers and corrosion of tendons. The poorest conditions among bridges are in the reunited (eastern) federal states.

Bridge Management

The German BMS is being developed into a comprehensive management system for structural maintenance. It is a tool for roadway agencies of the states and federal institutions. It identifies the programs of work required to obtain improvements at the project level, maintain structures in an acceptable condition, and meet network-level strategies in conformance with long-term objectives and budgetary restrictions. At the federal level, BMS provides an overview of the conditions of structures at network level, estimates future funding requirements, and develops strategies to achieve long-term objectives. At the state level, the BMS operates from the bottom up. Object-related analysis and assessment procedures operate on the results of bridge inspections. Subsequently, the results are optimized on the network level and integrated in network-wide maintenance programs. All computer programs are coordinated. Extensive transparency is guaranteed, and direct interventions are possible. The existing computer program SIB-Bauwerke

(Road Information Database Structures) is integrated to provide structural data for other systems now in development.

The following computer programs are in the development stage:

- BMS-MV to supply the information needed by subsequent computer programs (2005)
- BMS-MB to evaluate maintenance alternatives on an object level (2005)
- BMS-EP to optimize maintenance planning on the network level and present maintenance programs (2005)
- BMS-SB to evaluate object-related maintenance strategies on the network level

At the federal level, information from the database BISStra (Federal Road Information System), and the outputs from state-level planning are reviewed. The BMS for federal authorities operates from the top down. Currently, long-term forecasts of expenditures are prepared. Draft maintenance programs from the state level are analyzed, and annual measures of completed maintenance are analyzed. Working with the available budget, the federal review recommends direct interventions in the maintenance practice and revisions to technical rules. The federal review uses a computer system titled ISBW (Information System Structures) to analyze structural data and BMS-SB to analyze maintenance scenarios. Procedures are continuously refined.

An important administration task is observing and inspecting the structural inventory. To ensure a constant supply of reliable data on existing structures, the structural data are registered, stored, and evaluated by state administrative authorities with the help of electronic data processing equipment. In Germany, data are acquired and stored in accordance with the instructions ASB (Road Database Instructions), 1998 edition. The SIB-Bauwerke program (Road Information Database—Structures) is intended to register, store, and evaluate structural data furnished by state agencies. In addition, SIB-Bauwerke stores data on inspection results, known damage, maintenance measures, and maintenance costs. SIB-Bauwerke can produce network-level statistics for structural data. In the future, SIB-Bauwerke and BMS-MV will share common catalogues for possible maintenance actions (mapped to structural damage), and costs of actions. In addition, the programs will have deterioration models for structural elements, and will recognize the effects of maintenance measures. As a set, these information programs form a basis for prioritizing maintenance actions at the structural level and optimizing actions at the network level.

To improve the information at the federal level, the Federal Ministry of Transport, Building, and Housing developed the database BISStra and the ISBW analysis package. BISStra has links to traffic- and accident-related data, and has geographic information system (GIS) capabilities. The systems conform to German standards OKSTRA for object catalogs.

According to the German inspection guidelines (DIN 1076, RI-EBW-PRUF), each damage is recorded separately in terms of its type, position, extent, and effect by taking the ASB-code into account. An assessment of the damage influence on deterioration and a recommendation for repair are added. Analyses of damage data are developed in BMS-MV, yielding information on maintenance alternatives, costs, and consequences. For this purpose, knowledge catalogues in combination with analysis procedures were developed. A catalogue of actions was created in conformance with German maintenance guidelines. For each type of damage, a number of maintenance actions are given (for example, repair, rehabilitation, and replacement). For each action, the expected improvement in condition and the effect on future deterioration rate are included. The catalogue of actions is combined with a cost catalogue that includes direct costs, the duration of actions, and the kinds and costs of traffic control. To identify efficient maintenance projects, all actions at a structure are bundled. Technical strategies are defined at the element level. For each structural element, a deterministic deterioration model forecasts future values of condition. Damage-related intervention intervals are established using two thresholds on condition—an upper bound at which an action may be taken, and a lower bound at which action must be taken.

For each structure, the maintenance alternatives are generated for the main inspection interval of 6 years and valued by cost/benefit analysis for a valuation interval of 20 years. The result is given in form of a prioritized list. The alternative representing the lowest cost/benefit ratio is the most urgent one. The valuation not only covers owner costs, but also user and environmental components. The cost components are calculated by taking into account the defined procedures of the EWS-97 (recommendations for economic analysis on roads). Time, operation, noise, pollution, and accidental costs are considered. The owner benefit is represented by the calculated remaining value of the structure at the end of the valuation interval. Deterioration within the valuation period is included.

Because of the restricted budget and other boundary conditions, it is not possible to consider all of the best alternatives for all structures in the frame of the maintenance plan. The maintenance plan must be optimized. Two basic tasks have to be solved:

- Define the maintenance alternatives in a way that a minimum budget is realized for a given network-wide condition of structures.
- Define the maintenance alternatives in a way that an optimum network-wide condition is realized for a given budget.

The following boundary conditions are considered: yearly budget restrictions, minimum maintenance standards, direct interventions, and favor measures along the same route. Optimization is performed within BMS-EP. Maintenance programs are formed by state administrations based on financial restrictions and the allocation of funds by federal authorities. Maintenance programs coordinate maintenance for pavements, structures, and other elements of the federal network. Programs are presented as road network plans. For pavement maintenance, the guideline RPE-Stra (guideline for maintenance planning on roads) was introduced. A compatible guideline for structures is RPE-ING, which reflects BMS procedures that will be introduced in 2005. The computer program BMS-SB is being developed to describe the effects of maintenance strategies (e.g., intervention times and defined budget) on the forecast of condition and fixed assets. BMS-SB contains a macrolevel simulation model for large networks of structures in which maintenance program decisions are made on the object level. Maintenance strategies are considered by variable threshold values for intervention for repair and replacement. Results are network-wide distributions of condition index, yearly maintenance costs, and fixed assets during the evaluation interval. The user can set the evaluation interval. BMS-SB is connected to SIB-Bauwerke, and uses its structural data. Additional information is available at www.sib-bauwerke.bast.de/.

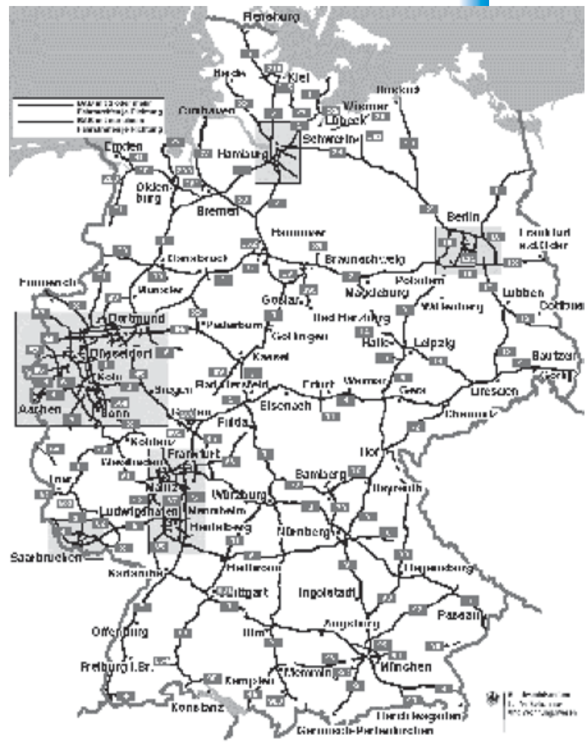


Figure 20. German road network.

Bridge Inspection

Germany has three levels of routine inspections: superficial, general, and major. Special inspections are made at bridges after floods, accidents, or other severe events.

Superficial inspections occur 4 times a year. General inspections occur every 3 years. Major inspections occur every 6 years. Major inspections are thorough examinations of all parts of bridges, producing complete reports of conditions and defects. General inspections are checks on the growth of known defects and examinations for new defects. Superficial inspections check for the appearance of significant new defects.

DIN 1076, *Engineering Structures in Connection with Roads; Observation and Inspection*, regulates the technical observation, inspection, and testing of the stability, traffic safety, and durability of bridges and other engineering structures for roads. Inspections are performed by experienced civil engineers who record damages and faults directly at the structure using the SIB-Bauwerke program system. Aims of inspection are the following:

- Detect the presence of defects affecting traffic safety, structural safety, and durability.
- Assess defects and determine the condition of a structure.
- Determine the cause and extent of deterioration.
- Evaluate the effectiveness of different repair techniques.
- Provide information for further investigations.
- Verify the inventory data.

Training

In Germany, bridge inspectors must have formal education as civil engineers and 5 years' experience as bridge engineers. A 1-week federal training course covers all aspects of inspection. Additional courses, often dealing with special structures or tasks, are offered at the state level. Continuing training occurs at an annual federal conference for bridge inspections. Inspectors also have physical requirements, including being able to do the walking, climbing, and other activities required by inspection, and not being colorblind.

Standards, Guides

German guides and standards for inspection of structures and for standardized reporting of condition include the following:

- DIN 1076, *Inspection And Testing Of Engineering Structures In Connection With Roads*, 1999
- Guideline RI-EBW-PRÜF, *Recording And Assessment Of Damages*, 1998
- ASB *Structure Inventory*, 1998 (coding manual for SIB-Bauwerke)

The DIN 1076 standard is a long-standing document that first appeared in 1929. It has had a series of updates, the most recent in 1999.

DIE BAUNORMUNG

MITTEILUNGEN DES DEUTSCHEN NORMENAUSSCHUSSES

SCHRIFTLEITER: REGIERUNGSBAUMEISTER a. D. KARL SANDER

8. Jahrgang | 20. September 1929 | Nr. 8/9

Noch nicht endgültig

Überwachung und Prüfung eiserner Straßenbrücken

DIN Entwurf 1 E 1076

Figure 21. DIN 1076.

Budgets for Inspections

Inspections are funded at about EUR45 million a year (US$49 million), about 0.1 percent of the replacement value of the bridge inventory. About 70 percent of inspections are performed by staff at regional road construction offices or state offices for road construction. Other inspections are performed by consultants.

Condition Ratings

The condition rating scale extends from 1 (best) to 4. Defects are reported both as a condition rating and a damage description: stable (slow or no growth of damage), threat to durability, or threat to traffic safety. The combination of condition rating and a description as a threat to durability or traffic safety reveals the significance of a defect and the urgency of its repair.

NDT

German Federal Institute for Materials Research and Testing, Bundesanstalt für Materialforschung und -prüfung (BAM), publishes the *ZfP Bau Kompendium*, a comprehensive guide to testing methods for materials including construction materials. “ZfP” is a commonly used abbreviation for Zerstörungsfreie Prüfung, or nondestructive examination. The compendium, in German, is available on the Web at www.bam.de/service/publikationen/zfp_kompendium/verz/hand.html

Germany employs a number of testing methods for both structure investigations and research projects:

- Ground-penetrating radar is used to detect tendon location in prestressed bridge beams. The current work is an experimental project on decommissioned beams.
- Half-cell potentials in bridge decks are mapped with a hand-operated rolling electrode. In a research study, concrete cover is removed and electrical potentials are correlated with corrosion of rebars.
- Magnetic flux leakage is used to detect wire breaks in prestressing tendons. Magnetic mapping is automated by a scanning magnetic detector mounted on a track.
- Ultrasonic testing for concrete members uses a mountable cluster of transducers.
- Impact-echo testing is used for voids in grouts in tendon ducts.
- Laser scanning determines the interior profile of tunnels, and can detect crack openings as small as 0.1 mm (0.004 in). Laser scanning combined with thermographic imaging can detect voids behind tunnel liners.

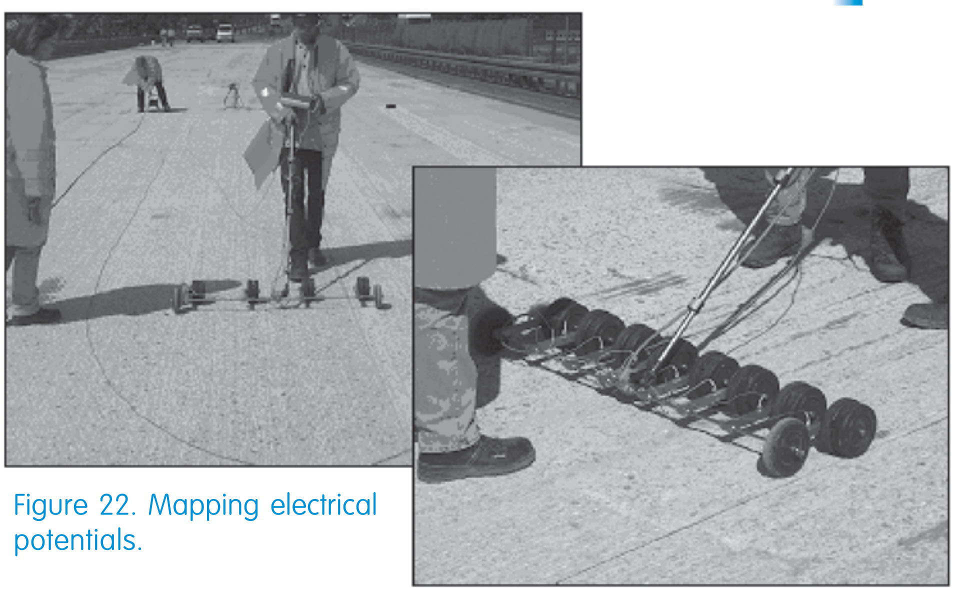


Figure 22. Mapping electrical potentials.

Figure 23. Magnetic detection of wire breaks.

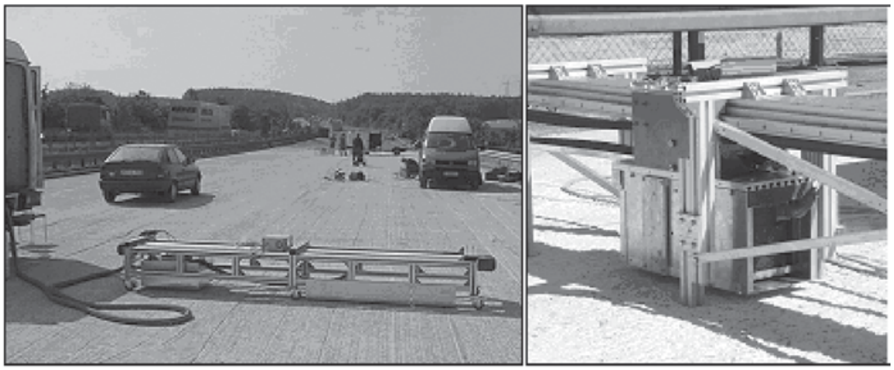


Figure 24. Magnetic detection of wire breaks.

Long-Term Monitoring

Germany uses long-term monitoring to study structural behavior, especially where investigations are needed to determine progress of deterioration or estimate load capacity. Monitoring is used to verify models of load and response. The German point of view is that monitoring is never a substitute for regular inspection.

Load Tests

Load testing is performed using a special, mobile load facility called BELFA. The equipment is a self-mobile reaction frame that provides controlled loading of spans. Load is a combination of dead weight (water) and jacking against reaction points. More information is available at www.belfa.de/index_e.htm.

Table 21. BELFA specifications.

Transport mode	length 22.5 m
Test mode	length 22.5 m to 34.5 m
Span for loading tests	6.0 m to 18.00 m
Vehicle mass (without ballast)	67.5 t
Steel ballast	10 t
Water ballast	20 t

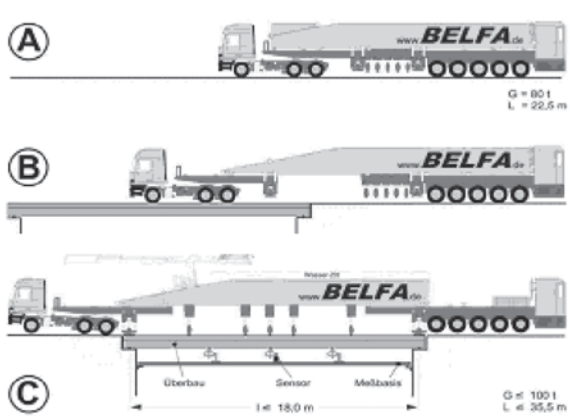


Figure 25. Load tests with BELFA.

Operations

Loads

DIN 1072 is the standard for traffic design loads for German bridges. Allowable truck loads have more than doubled since the 1920s, increasing from 15 t gross weight to 44 t. Axle loads have increased from 6 t to 12 t. Current design loads conform to the Eurocode 1.

Permit Loads

Permits for heavy goods vehicles are issued at the state level in conformance with federal regulations for motor vehicles (STVZO) and, similar to U.S. practice, permits are available both for single transits and repeated use during a fixed period. Traffic and construction administrators are both involved in permits. The goals are to minimize the number of overload transports, encourage the use of other transportation modes, and, if possible, divide overloads.

Fees for permits cover administrative (processing) costs. Charges are not based on weight, routes for overloads are not specified, limits on gross weights are not enforced, and the transit of the load is not supervised. In the future, Germany plans to use a set of WIM stations to monitor truck loads.

SIB-Bauwerke contains all data required for assessment of load capacity, and all checking for clearances.

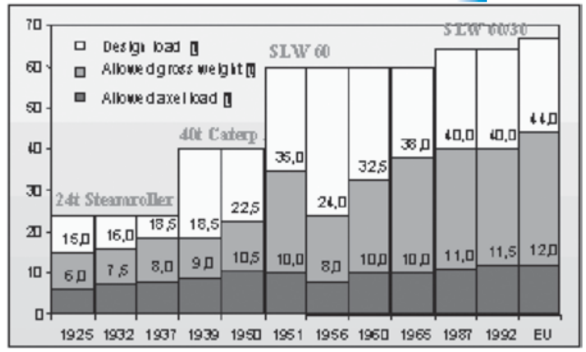


Figure 26. German design loads.

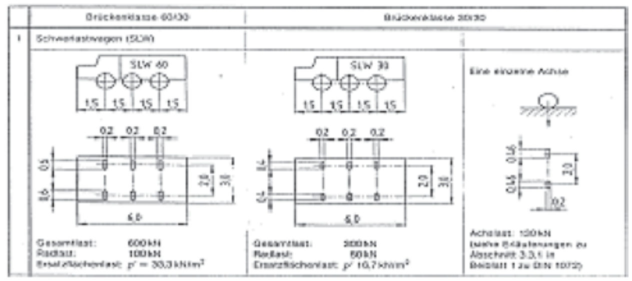


Figure 27. German design loads.

Max. gross weight	18–40 t
Max. axle load	single axle 11.5 t double axle 17.6–20 t
Max. height	4 m
Max. width	3 m
Max. length	15–23 m

Table 22. STVZO limits for vehicles.

Action	Description
Service maintenance	Action in support of traffic operations; maintenance of lights, signs, and signals; and winter maintenance.
Routine maintenance	Small construction projects to guarantee function and traffic safety without influencing condition.
Repair	Larger construction projects to restore condition of the structure or its components.
Strengthening	Construction projects to improve load capacity.
Superstructure rehabilitation	Demolition and replacement of the entire superstructure.
Renewal	New structure.

Maintenance

Germany uses the following definitions for actions:

Action **Description**

Service maintenance Action in support of traffic operations; maintenance of lights, signs, and signals; and winter maintenance.

Routine maintenance	Small construction projects to guarantee function and traffic safety without influencing condition.
Repair	Larger construction projects to restore condition of the structure or its components.
Strengthening	Construction projects to improve load capacity.
Superstructure rehabilitation	Demolition and replacement of the entire superstructure.
Renewal	New structure.

Budgets for Maintenance

Service maintenance for traffic safety and operations is funded at about EUR750 million a year (US$818 million). The work includes cleaning, mowing, winter maintenance, and traffic equipment maintenance. Routine maintenance includes minor repairs that do not improve the condition of structure. The annual funding is about EUR150 million a year (US$164 million). Actions include sealing of joints, cleaning of drainage, small concrete repair, and maintenance of sign structures. These actions are executed by regional road maintenance operation centers or contractors.

Repairs, strengthening, and replacement are funded at EUR300 to EUR350 million a year (US$330 to US$380 million). This is about 0.8 percent of the replacement value of structures. Funding will increase to EUR500 million a year in the future. These projects improve the condition of bridges and assure structural safety and durability. Planning is performed by the regional road construction office. Construction activities are provided by contractors.

Findings in Germany

BMS

Structures management systems. The German maintenance management system includes bridges, culverts, retaining walls, sign structures, and tunnels.

Service life models. Germany is developing predictive performance models for bridges based on anticipated service life. These will function as deterioration models.

Complementary software packages. Germany employs two versions of its Bauwerke software. A simple version allows quick evaluation of bridge conditions and urgent repair needs. Additional modules provide network optimization.

Inspection

Training. German bridge inspectors are civil engineers with bridge experience and federal training for inspection.

Manuals. German standards for inspections are long standing. The basic standard DIN 1076 appeared in the 1920s and has been revised frequently, most recently in 1999.

Testing and NDT. Germany uses a number of NDT methods for investigating structures, including ground-penetrating radar, half-cell potentials, ultrasound, magnetic flux leakage, and impact-echo.

Operations

Concrete durability. Tests for construction materials are documented in the BAM compendium. Engineers can specify the requirements for materials, such as resistance to water penetration, and identify the appropriate test basis for acceptance.

BELFA load test. Germany uses the BELFA vehicle for controlled, diagnostic load testing of bridges.

Clearances. Legal limits on truck height are a bit less than design values, giving a little extra room to avoid accidents.

NORWAY

Norwegian Public Road Administration

The Norwegian Public Roads Administration (Statens vegvesen) has a central organization, five regions, and 30 districts. The central organization employs 10 people. Regional offices employ about 30 people each. All construction and maintenance are done by contract. In each region, one engineer is responsible for bridges and is involved in all activities: BMS, inspections, maintenance, repair, strengthening, and construction.

Figure 28. Road districts in Norway.

Bridge Inventory

In Norway, a bridge is a structure spanning more than 2.5 m (8.2 ft). The public roads agency manages 17,060 bridges. Of these, 11,020 are nationally owned and 6,040 are locally owned. The average age of bridges is 32 years. Average length is 25 m (82 ft). Total length of bridges is 500 km (311 mi). The calculated replacement value is US$7.3 billion. Expenditures for maintenance and repair on national bridges in 2002 were US$42 million.

Table 23. Length distribution by number of bridges.

Total length 2.5–9.9 m	59%
Total length 10–24.9 m	22%
Total length 25–99.9 m	12%
Total length 100–>1000 m	7%

Table 24. Length distribution by deck area.

Total length 2.5–9.9 m	12%
Total length 10–24.9 m	11%
Total length 25–99.9 m	22%
Total length 100–>1000 m	55%

Table 25. Bridge distribution by material of construction.

Concrete	70.6%
Steel	28.8%
Stone	0.4%
Timber, others	0.2%

Little new construction is being done today, so the bridge stock is aging. The network average condition rating in 1998 was 0.943, and by 2002 it had risen (worsened) to 1.235. Condition at 3.0 or greater is unacceptable. Currently, 353 bridges (2.3 percent of deck area) have a condition greater than 3.0. The backlog in maintenance and repair amounts to $314 million, about eight times the annual budget for bridges.

Bridge Management System

The Norwegian BMS, BRUTUS, includes bridges, tubes, culverts, retaining walls, tunnel portal constructions, concrete tunnels in the ground, ferry berths, and quays. BRUTUS was developed especially for Norway. Development and computer infrastructure cost $1.2 million. Estimated annual savings are $2 million. The savings are because of efficiency, consistency, structured processing, improved performance (handling) procedures for data, and easier and more rapid access to bridge information.

BRUTUS is a management and information system that serves the complete life cycle of structures. The BRUTUS software houses guidelines for bridge management; handbooks for bridge inventory, inspection, and maintenance; and online training in BMS software, inventory, and bridge inspection and maintenance practices. BRUTUS stores photographs of bridges and records changes to bridges.

The BRUTUS user network includes five regional offices and 30 districts. The main national database operates in client/server mode. BRUTUS software also can run on a stand-alone basis with a subset database for a single region or district.

Maintenance Programming

Alternative strategies for repairs are investigated if the estimated repair costs exceed 20 percent of a bridge's replacement value. Replacement is considered if repair costs exceed 50 percent of a bridge's replacement value.

Typical strategies for repair include the following:

- Temporary action, or the completion of a minor repair to postpone major work or replacement of a bridge
- Major action, or extensive repair work to significantly extend the remaining service life of the bridge

- Replacement of a bridge element or a bridge

Selection of a strategy considers several factors, including bridge age, remaining service life, load rating, geometrics such as bridge width/road curvature, clearances, traffic safety, traffic demand, future traffic demand, aesthetics, and historic value.

Inspection

Types of bridge inspections in Norway are listed in table 26.

Table 26. Inspection types and intervals.

Type	Occurrence
Acceptance inspection	New construction or new repair
Warranty inspection	Before the warranty expires, about 3 years
General inspection	Every 1 or 2 years
Major inspection	Every 5 or 10 years
Major inspection under water	Every 5 or 10 years
Major inspection of cables	Every 5 years
Special inspection	As needed

The acceptance inspection occurs when a new bridge or a repair work is handed over from the contractor. The inspector is a civil engineer with good general knowledge of bridge construction and durability. A visual check is made of the entire bridge. Measurements and material investigations are made if appropriate to the repair project. Faults, if any, are identified, and faults may be corrected or accepted based on the judgment of the inspector. Plans for continuing inspection and maintenance of the structure are established. Needs for access equipment at future inspections are identified.

The warranty inspection occurs before the claims deadline in the warranty period of a construction contract. The inspection is similar to an acceptance inspection. Plans for continuing inspection and maintenance may be modified at this time.

General inspections occur every 1 or 2 years. The general inspection is a visual check of the bridge for significant defects. Access equipment is not used. The inspector must have general knowledge of bridge construction and durability. For special structures, such as cable-stayed bridges and suspension bridges, the inspection must be performed by a civil engineer experienced with these structures.

Major inspections occur every 5 to 10 years. The inspection is a complete visual check of the bridge and will often include measurements and material investigations. Access equipment is used and a complete catalog of defects is generated. The inspection is performed by a civil engineer with a good general knowledge of bridge construction and durability. Plans for continuing inspection and maintenance are updated.

Special inspections occur as needed. Depending on the conditions being addressed, the inspection may include visual checks, measurements, or material investigations. Special inspections often are needed to evaluate repair strategies.

Standards and Guides

Norwegian guides and handbooks for inspections include the following:

- HB 147—Guideline for bridge management covering general management, inspection, and maintenance
- HB 129—Inventory handbook
- HB 136—Inspection handbook

Condition States

Visual inspection yields a catalog of defects at a structure. Inspectors report each defect, the consequences of the defect, and the degree of severity. Codes for consequences and degree are shown in tables 27 and 28.

Table 27. Norwegian defect consequences codes.

Code	Description
B	Damage/deficiency threatening load carrying capability
T	Damage/deficiency threatening traffic safety
V	Damage/deficiency that may increase maintenance costs
M	Damage/deficiency that may affect the environment/aesthetics

Table 28. Norwegian defect degree ratings.

Rating	Description
1	Slight damage/deficiency, no action required
2	Medium damage/deficiency, action needed during next 4–10 years
3	Serious damage/deficiency, action during the next 1–3 years
4	Critical damage/deficiency, immediate action required or within ½ year at the latest

Field Computers and Field Inspection

Inspection data is entered at the bridge site or in the office from written reports. The inspection report contains condition ratings, description of the necessary maintenance and repair, the inspector's estimate of costs, and photos of the bridge.

Wireless access to BRUTUS is available. The system provides a download of inventory, inspection, and maintenance records for selected structures so inspectors can have these records in the field. BRUTUS can store data from measurements and material tests.

NDT

NDT and field-testing methods are used most often in research projects. Strain gages have been used in stress measurements in steel elements, modification of beam hinges in a concrete box girder bridge, and dynamic response of suspension bridges to wind.

Operations

Normal Loads

Normal permissible vehicles have a single axle load not greater than 210 kN (47 kips), a tandem axle load of 65 kN plus 120 kN (15 kips plus 27 kips), or a triple axle load of 70, 70, 100 kN (16, 16, 23 kips). The gross weight limit is 300 kN within a 7-m length (68 kips in 23 ft) and 500 kN within a 16-m length (113 kips in 53 ft). A dynamic load equal to 40 kN (9 kips) is added to the heaviest axle. Permissible width is 2.55 m, height is 4.5 m, and vehicle length is 22.5 m (8.4 ft, 14.8 ft, and 74 ft).

Permit Loads

Regional and district offices can issue permits for transits involving vehicles that satisfy limits related to total load, vehicle length, and number of axles, and for loads that will transit bridges known to have adequate load capacity (this includes all bridges built after 1969). For vehicles beyond these limits, or for transports that must transverse older bridges, permits must be issued through the central administration office in Oslo. Moreover, during the transit, vehicles must move slowly, be escorted by police, and cross bridges along their centerlines.

The transport company pays for all work by the public roads administration and the police. Calculations needed for each bridge on the route are prepared by consulting engineers and filed with the roadway agency.

Maintenance

Routine maintenance includes actions such as washing, removing debris, removing vegetation, removing spalled concrete, patching potholes, making small repairs to parapets, making repairs to asphalt joints, and doing other joint maintenance.

Preventive maintenance includes surface protections, renewing the topcoat on steel, and waterproofing on the bridge decks.

Special maintenance includes maintenance of equipment, such as mechanical systems on movable bridges.

Budget for Maintenance

Bridge actions are planned for a 10-year horizon, but budgets are annual and have separate funds for maintenance, repair, and strengthening and renewal. Strengthening and renewal are considered investments that are additions to the capital value of the bridge population. Budget information is summarized in table 29.

Table 29. Norwegian budget information.

Activity	Budget	
	million NOK	million US$
Inspections	37	5.10
Maintenance	30	4.20
Repair, foundations	7	0.97
Repair, concrete	100	13.90
Repair, steel	71	9.90
Repair, stone, timber	3	0.42
Pavement waterproofing	26	3.60
Bridge equipment	44	6.10
Ferry berths	66	9.20

Findings in Norway

BMS

Structures management system. Norway's BRUTUS system provides maintenance management for bridges, culverts, ferry berths, quays, retaining walls, and tunnels.

Inspection

Inspection interval. Norway conducts general inspections every 1 or 2 years and major inspections every 5 to 10 years.

Manuals. Norwegian guides for bridge inspection give illustrated examples of distress, how to measure and report distress, and what maintenance actions to recommend. A single defect type is linked explicitly to condition ratings, basis of evaluation and reporting, and usual methods of repair.

Operations

Washing. Norway washes bridges to remove deicing salts and other contaminants at the surface of members.

SOUTH AFRICA

South Africa's 40.6 million people rely heavily on road transport. The roads are used by motor vehicles and pedestrians alike. In rural areas, roads lack sidewalks and pedestrians traveling between villages must walk at the margin of the pavement. Pedestrian accidents result in 28,000 deaths or serious injuries each year. This rate is about 400 accidents per 100 million vehicle-kilometers traveled, and totals some 512,000 traffic accidents a year. The costs to the South African economy are R14 billion per year (US$1.8 billion).

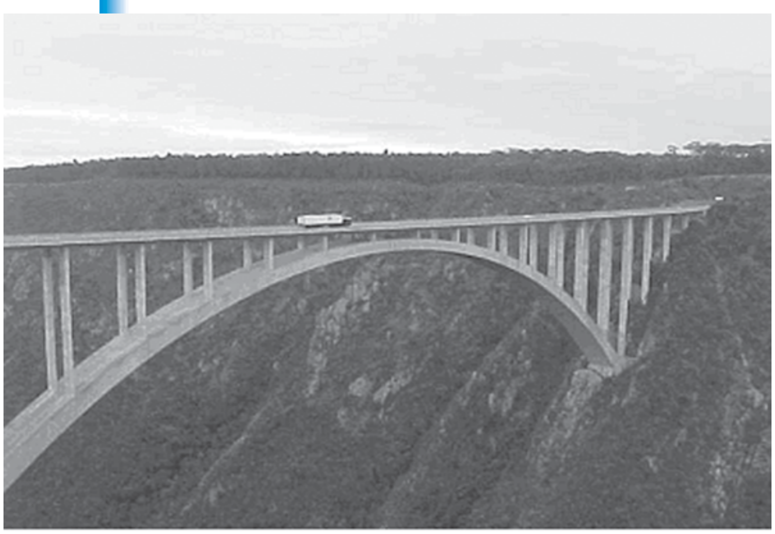


Figure 29. South African highway bridge.

Roads

South Africa has 62,000 km (38,500 mi) of paved roads, and 690,000 km (428,000 mi) of unpaved roads, of which 221,000 km (137,000 mi) are undeclared.

South Africa has 6 million licensed drivers. It has 6.73 million registered vehicles, including 3.86 million motorcars, 252,000 minibuses, 24,000 buses, 227,000 trucks, 1.2 million light delivery vehicles (bakkies and cargo vans), and 1.17 million other vehicles. These vehicles travel, in the aggregate, 98 billion km a year (61 billion mi), or about 40 km (25 mi) per vehicle per day. Fuel sales amount to about 9,500 million liters (2.5 billion U.S. gallons) per year.

Figure 30. Colt bakkie. (*Motoring* ZA 2004)

Table 30. South African roads.

D–DEGREE of defect	Severity of defect
E–EXTENT of defect	Prevalence of defect within the bridge element
R–RELEVANCY of defect	Impact of the defect on structural integrity and/or user safety
U–URGENCY of defect	Recommended time for repair

Figure 31. South African road network.

Trunk roads include 7,200 km (4,500 mi) of designated national routes and 4,000 km (2,500 mi) of associated provincial routes. Trunk roads carry more than 70 percent of the vehicle-miles in South Africa. The national system has 1,900 km (1,200 mi) of toll roads. About 58 percent of the network road miles are more than 21 years old, and much of the trunk road system was built in the 1960s.

Administration

The South African National Department of Transport develops policy, strategy, and high-level regulation for all modes of transport. The department directs operating agencies, including the South African National Roads Agency (SANRAL). SANRAL administers the national road system. SANRAL's assets in roads, structures, and equipment are valued at R30 billion (US$3.8 billion). Beyond SANRAL, there are nine provincial departments of transport and numerous municipal transport agencies.

SANRAL is decentralized. Four regional branches, with a total staff of about 120, administer the road sections in their regions. SANRAL outsources most road design and construction work to private firms.

Maintenance is outsourced two ways. Some routes are operated on a toll-concession basis. On these conceded routes, the contractor maintains roads and bridges, and manages a profit by collecting tolls. Toll rates are negotiated with SANRAL. Most concessions extend for about 400 km (250 mi) of route and last for 30 years. Conceded roads are not required to accept abnormal (permit) loads. Routes that are not conceded are funded by a 10 percent share of the motor fuels tax.

Figure 32. South African provinces.

Bridge Inventory

South Africa defines a bridge as a span of at least 6 m (19.7 ft). Trunk roads have 2,100 bridges. Most highway bridges are reinforced concrete or prestressed concrete. Few steel bridges are in road service, although a number of railroad bridges are steel. Construction type correlates with bridge age and road class. Older bridges, bridges on minor routes, and bridges in remote locations are reinforced concrete. On the national roads and major provincial roads, prestsressed concrete bridges are used for most spans over 15 m (49 ft).

The national rail system, SPOORNET, has 10,000 bridges.

Figure 33. South African river crossing.

Figure 34. Vehicle and pedestrian crossing.

Bridge Management

SANRAL maintains an integrated information management system using Oracle. The information system provides inventory functions for structures (including locations, types, dimensions, age, etc.), accepts inputs from bridge inspections, and keeps historical records of conditions. The system provides a common graphical user interface (GUI) and a common database for all roads structures. The information system offers standardized creation and distribution of electronic documents, and has links to geographic information systems (GIS). The database contains most roadway structures, including bridges, retaining walls, culverts, and sign supports. South Africa has an internal data network for access by governmental offices (both national and provincial), Internet access for public data, and a special access for business partners such as maintenance contractors.

The structures information system keeps complete historical records of maintenance actions, including descriptions of work done for each bridge, name of contractor, duration of the project, date of completion, and cost of work. The information system stores the needed and/or planned work for each structure, including maintenance and improvements and their costs.

The information system underlies modules for management of various classes of structures. Each module performs analyses and forecasting for its class, and offers customized reports. The bridge management module is STRUMAN, developed for SANRAL by the Council for Scientific and Industrial Research (CSIR). STRUMAN produces a priority list of bridge repairs, uses deterioration models to forecast future needs, identifies immediate work programs, and optimizes maintenance program plans.

The onscreen interface for STRUMAN has the appearance of spreadsheet tables. Navigation among related tables is familiar to spreadsheet users. Data is entered in cells. The GUI displays inspection forms, and this portion of the BMS can be run on field computers for use at the bridge sites during inspections. The GUI is also adapted to the use of pen-based tablet personal computers. STRUMAN accesses the structural information system to retrieve photographs of bridges, including photographs of defects from previous inspections. New photos can be added with each inspection. All photos can be linked to schematic plans of bridges to more clearly define the location and extent of defects.

In its current operation, STRUMAN is a defect-based management system, reflecting the backlog of repairs needed in the South African bridge network. STRUMAN helps the national road administration identify and repair defects that have a direct effect on the structural integrity of bridges or otherwise threaten the safety of users. STRUMAN offers a slate of projects optimized to reduce risk under a limited budget.

CSIR has produced versions of STRUMAN for many agencies beyond SANRAL, including the city of Cape Town, the N3 Toll Concession Ltd., the provincial administration of the Western Cape, the KwaZulu-Natal Department of Transport, the Mpumalanga provincial government, the South African Railways, the Taiwan Area National Freeway Bureau, the Botswana Roads Department, the Namibia Roads Authority, the city of Windhoek, and the Swaziland Ministry of Public Works.

Further information on CSIR is available in Appendix C and at www.csir.co.za.

A STRUMAN users group, formed in South Africa in 2001, provides input on the continuing development of the system.

Condition Ratings

In the South African bridge reporting system, defects are assigned ratings for degree, extent, and relevancy (DER). The DER system employs ordinal integer values in four categories (table 31). Values range from 0—no defect—to 4—critical defect (table 32).

Table 31. DER categories.

D–DEGREE of defect	Severity of defect
E–EXTENT of defect	Prevalence of defect within the bridge element
R–RELEVANCY of defect	Impact of the defect on structural integrity and/or user safety
U–URGENCY of defect	Recommended time for repair

Table 32. DER rating values.

	Degree	Extent	Relevancy	Urgency
0	None			Monitor only
1	Minor	Local	Minimum	Routine
2	Fair	>Local	Moderate	< 5 years
3	Poor	<General	Major	< 2 years
4	Severe	General	Critical	ASAP

Performance Indicators

Performance indicators are defined for defects and bridges. Each defect has a condition index, Ic.

$$I_c = 100\left[1 - \frac{(D+E)R}{32}\right] \quad \textbf{Eq. 1}$$

Ic equals 100 when there is no defect, and equals 0 when D and E and R are all at value 4. A defect is critical if the Ic is below 40. The index, Ic, is the dependent variable in the STRUMAN deterioration model. Straight-line deterioration is proposed with the Ic declining at about 5 points per year.

Each bridge has a bridge condition index (BCI). The BCI is the sum of condition index values, Ic, weighted by average daily traffic among a population of structures.

$$BCI_n = \frac{\left(\sum_j Ic_j\right) ADT_n}{\sum_i ADT_i} \quad \textbf{Eq. 2}$$

BCIn = the bridge condition index for structure n

SðIc = The sum of condition index values for all relevant defects in structure n

ADTn = The average daily traffic for structure n

SðADT = The sum of values of average daily traffic for all structures in the prioritization process.

The BCI gives a combined indicator of importance of defects and importance of the bridge. A high BCI value indicates a good bridge and a low value indicates a poor bridge. The further scaling by traffic volume will tend to increase BCI for heavily traveled bridges.

Repair Priorities

Priorities for repairs are developed from two considerations. First is structural adequacy, as indicated by BCI values. Second is functional importance, an evaluation computed from road class, bridge load capacity, detour length, etc. Generally, network-level optimization seeks the set of projects that offers the greatest reduction in defect relevancy, R, for a given budget.

Automated optimization yields a first list of repair projects. Next, projects for bridges are coordinated with projects for pavements in the same road section. Usually, a repair project at a bridge will attempt to remedy all relevant defects, not merely those with the highest priority values.

Bridge Inspection

South African practice includes routine inspections of two types, monitoring and principal. Monitoring inspections are performed by maintenance personnel, and occur at frequent but irregular intervals. Monitoring is a quick look at a structure to discover significant new defects, if any, and to note the current state of known defects. Monitoring inspections are part of routine maintenance surveys for road sections and quick surveys conducted after accidents, floods, cyclones, or other extreme events.

Principal inspections are conducted every 3 to 5 years by inspectors who are experienced in bridge design, maintenance, and rehabilitation. Principal inspections make a thorough examination of bridges and record all defects. The principal inspection produces a full written report and photographs of all defects.

There are two event-related inspections. The project-level inspection is a directed examination of a bridge to collect data needed to prepare contract documents for a repair project. An acceptance inspection is made after repairs are complete.

Principal inspection

The principal inspection seeks to record all defects and to report the immediate or potential effect of defects on structural integrity. All main elements of a bridge are inspected (table 33), and all defects are sought. Inspectors, through experience, seek defects of known types (table 34).

Table 33. Main elements of a bridge.

Approach embankment	Surfacing	Bearings
Embankment protection works	Superstructure drainage	Drainage features
Guardrail	Curbs/sidewalks	Expansion joints
Waterway	Parapet/handrail	Longitudinal members
Abutment foundations	Pier protection works	Transverse members
Abutments	Pier foundations	Deck slab
Wing/retaining walls	Piers and columns	Miscellaneous items

Table 34. Defects in bridges.

Spalling	Cracks—bending, shear	Defective surfacing
Scour	Rotating abutments	Excessive deflections
Erosion	Defective drains	Expansion joints not watertight
Settlement	Defective guardrails	Defects on concrete surface
Honeycombing	Insufficient cover to reinforcement	Flood debris accumulation

The principal inspection reports a list of defects, not a set of conditions. Good condition of an element is implicit if no defect is reported. Extent is reported qualitatively, not quantitatively. Repair quantities are determined separately in project inspection once the decision is made to repair a particular bridge. The South African inspection form is organized on a single sheet. This form and photographs of defects make up the formal report. SANRAL requires paper reports, signed by the inspector, in addition to an electronic report to STRUMAN.

Training

Principal inspections are led by licensed professional engineers with experience in bridge design and training in bridge inspection. Consultants to SANRAL provide training courses for bridge inspectors. Quality of inspections is assured through annual review of a sample of bridges. In most years, some 2,000 bridges are inspected. Of these, 30 are inspected separately by senior SANRAL personnel.

Testing Methods

SANRAL evaluates concrete permeability as an indicator of the quality of protection of reinforcing steel. Cores are taken for structures in service. Oxygen permeability tests are executed in the lab, and these results are correlated with water permeability. Permeability to water, an important transport mechanism for contaminants in concrete, correlates with vulnerability to corrosion.

Operations

Permit Loads

The maximum normal load is a 56-t (123-kips) vehicle on 9 axles with a length of 22 m (72 ft). Normal vertical clearance is 4.9 m (16.1 ft) for older bridges and 5.6 m for newer bridges. Oversize loads are a continuing problem. Limits on clearance are often ignored. Worse, the posted clearances are sometimes wrong. Resurfacing operations can reduce a 5 m underclearance by 70 to 80 mm (3 in).

Loads that exceed limits on size or weight are termed superloads. The loading code is explicit for superloads. If limits on axle loads are met, then the superload can be represented as an equivalent distributed load. Stress analysis for superloads is usually a three-dimensional analysis employing ether a grillage or finite element model of the bridge. A limit state approach is used for evaluation. The load factor on superloads is usually 1.3.

Loads greater than 120 t (264 kips) require an engineering review of the structures along the proposed route. South Africa has a technical committee on abnormal loads. This committee directs the evaluation for specific cases to consulting engineers.

Superloads as great as 800 tons (1760 kips) have traveled on South African roads. One load traveled 600 km (375 mi) from a seaport to an industry site in the interior. SANRAL identifies a network of super routes for abnormal loads. Super routes offer superior load capacity at bridges and superior vertical and horizontal clearances.

Enforcement

National roads have truck load control stations that consist of a truck scale and a law court. Overloaded vehicles are impounded, and fines are assessed at the time of the infraction. The overload must be off-loaded at the weigh station before the truck can continue its trip.

South Africa plans to use weigh-in-motion (WIM) to monitor truck loads and enforce load limits. WIM can be used to select those vehicles that must be directed to load control stations for further checking.

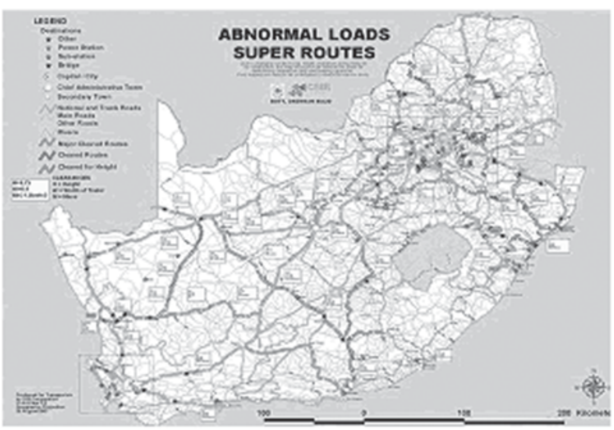


Figure 35. South African super routes.

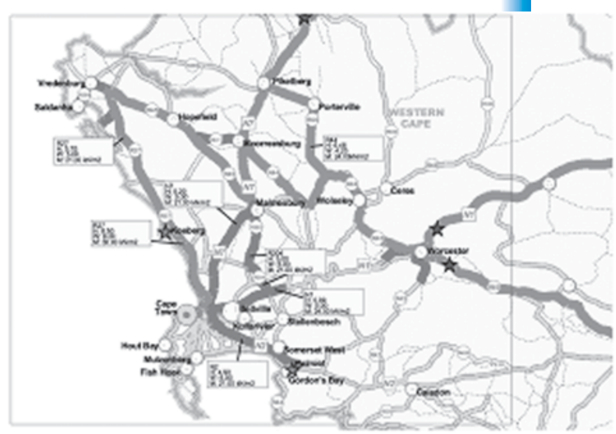


Figure 36. Detail of South African super routes.

In figure 36, note that for each bridge, clearances and load capacity are identified.

Table 35. Example of bridges on super routes.

Route	H, m	W, m	M, kPa	H, ft	W, ft	M, PSF
R27	5.7	5	21	18.7	16.4	438
R27	8.5	8	30	27.9	26.2	626
R44	6.48	4.25	24	21.3	13.9	501
N7	5.2	5	21	17.1	16.4	438
R304	5	5	21	16.4	16.4	438
N1	5	-	24	16.4	-	501
N2	4.9	5	21	16.1	16.4	438

Maintenance

Maintenance actions include repairing leaky joints and faulty bearings and resetting guardrails, especially after a collision. Theft also contributes to maintenance needs. Aluminum parts are taken from roads for their salvage value. Iron identification plates have been taken from bridges.

Provincial spending on roads is growing at a real average annual rate of 1.1 per cent. The backlog of bridge work in the road network is estimated at R23 billion (US$2.9 billion). Of this backlog, 53 percent is rehabilitation, 28 percent is improvements, and 19 percent is new construction.

Findings in South Africa

Administration

Conceded roads. Some roads in South Africa are operated as concessions. The contractor collects tolls and in exchange provides inspection and maintenance operations. SANRAL plans to expand concessions to include road and bridge construction. Contractors, following SANRAL specifications, will design and construct roads and bridges, operate the routes using agreed schedules of tolls, and inspect and maintain the routes.

Inventory

Concrete bridges. Most SANRAL bridges are reinforced concrete or prestressed concrete. National roads have few steel or timber bridges. Even on local and undeclared roads, reinforced concrete bridges predominate.

BMS

Photos and sketches. SANRAL's BMS stores photos of bridges, mostly collected during inspections, and links photos to scale drawings and sketches. Inspectors can use these links to drawings and sketches to convey the location and extent of defects.

GIS. Bridge records in SANRAL's BMS are linked to other geographical information systems. Links to photos, drawings, and GIS are provided through the structural information management system underlying the STRUMAN BMS.

Inspection

Inspection level and interval. South Africa has two levels of routine inspection, monitoring and principal. Monitoring inspections are frequent and cursory, requiring little training of technicians. Principal inspections occur at 3-to-5-year intervals, are thorough, and require licensed, experienced inspectors.

Internet data access. Inspection data can be entered using an Internet portal. Screens for online access imitate the paper forms used by inspectors. A written inspection report, signed by the inspector in charge, is also required.

DER condition ratings. South African inspectors report each defect, its extent, its relevance (to load capacity), and its urgency. The DER values are used in the SANRAL bridge management system as part of priority ranking of repairs.

Manuals. The scan team recommends that SANRAL's inspection manual be reviewed and compared with U.S. inspection practices.

Event inspection. South Africa uses project inspections as repair projects are being planned, and acceptance inspections after work is completed.

Maintenance Management

Defects in structures determine maintenance programming. South Africa has a backlog of deficient structures. Maintenance programs are reactive, striving to maintain safety at structures.

Performance Indicators. SANRAL's bridge management system uses condition index, Ic, to compute a bridge condition index, BCI. Index Ic is computed from DER ratings assigned by bridge inspectors. Priority for repairs is determined by the bridge condition (BCI) and the traffic volume (ADT).

Operations

Shipper pays for bridge improvements. When abnormal loads require greater strength or increased clearances at structures, the shipper pays for all necessary work.

Weigh-in-motion. South Africa plans to use WIM installations to screen trucks in advance of load control stations.

Load rating and load posting. Few bridges in South Africa are posted for load restriction, and there is little in-service evaluation of load capacity. The normal permissible truck load is 56 t (123 kips). Load rating calculations are required for permitting of loads greater than 120 t (264 kips).

Structural analysis. South African engineers routinely use three-dimensional analysis to evaluate load capacity of bridges.

Additional Items

Heavy traffic and the significant impacts of closure on some main roads has led South Africa to employ innovative construction methods. In Johannesburg, a cable-stayed flyover was built on the embankment parallel to a major route, and then swung 90 degrees horizontally to its final alignment. The bridge is shown on the cover of this report.

SWEDEN

Swedish National Road Administration

Vagverket, the Swedish National Road Administration (SNRA), has about 6,500 employees in 16 groups. These include the central office, seven regional offices, traffic policy, information technology, vehicle registrations, driver licensing, ferry operations, engineering consulting, contraction and maintenance, and road sector training.

Figure 37. Oland Bridge.

Four groups are profit centers: construction and maintenance, consulting services, ferry operations, and the road sector training. Profit centers operate as subsidiary companies of SNRA and compete with private contractors and engineering consultants for work in bridge design, construction, and maintenance. SNRA construction and maintenance holds 62 percent of SNRA routine maintenance contracts. SNRA consulting offers planning, design, and construction management services in structural, environmental, and geotechnical engineering, as well as road architectural design, traffic safety, and traffic information systems.

Work performed by SNRA includes strategic management, project planning, bridge work specification, bridge work procurement, and contract work supervision. SNRA performs about half of all bridge inspections. Work by consultants and profit centers includes bridge design, maintenance and repair projects, bridge construction, and bridge inspections. The Web address for SNRA is www.vv.se/for_lang/english/.

Bridge Inventory

The Swedish network has 138,000 km (86,000 mi) of public roads and 75,000 km (46,600 mi) of private roads receiving state subsidies. Sweden has 24,000 bridges on public and private roads. SNRA owns 14,700 bridges, municipalities own 6,100 bridges, and 3,200 bridges are privately owned. Sweden has 3,500 railway bridges.

The definition of a bridge changed in 1989. Previously, a bridge was a structure with a span of at least 3 m (9.8 ft). Today, a bridge must have a span of at least 2 m (6.6 ft). Bridges with spans less than 20 m (66 ft) make up 60 percent of the SNRA inventory. Bridges with spans greater than 50 m (164 ft) make up 15 percent of the inventory. The total deck area is 4 million m^2 (43 million ft^2), and aggregate length is 341 km (212 mi).

Most bridges are concrete structures. Though bridge construction peaked first in the 1970s and again in the late 1980s, a near-uniform distribution of bridges was built in each decade from the 1940s onward.

Table 36. SNRA bridges.

Material	Bridges
Concrete	10,330
Steel	3,226
Stone	868
Timber	22
Aluminum	4

Swedish bridges are designed for low maintenance. Expansion joints are avoided. New bridges with a total length of less than 90 m (295 ft) are built with integral abutments. Bridge beams are continuous over intermediate supports. The number of bearings is minimized. As a result, bridges that have neither bearings nor expansion joints number about 7,400, or about 50 percent of the SNRA inventory.

Figure 38. Swedish bridge with no joints or bearings.

Budgets

The SNRA bridge network has a replacement value of $4 billion. The annual maintenance budget is $86 million (2.2 percent of replacement value) and the budget for new construction is $90 million (2.3 percent of replacement value).

Table 37. SNRA budget values.

Replacement value	$7.3 billion
Maintenance and operations funding	$105 million/year
Improvements (to load-bearing capacity)	$18 million/year
New construction	$130 million/year
Preventive maintenance and operations	$15 million/year
Research and development	$1.8 million year

Bridge Management

SAFEBRO is the Swedish bridge management system. SAFEBRO is organized around object databases, a knowledge basis, and process modules. The object database contains a bridge inventory, condition data, user data, and work plans. The knowledge basis contains deterioration models, average cost data, definitions of performance measures, standard repair actions, and their application domains. Processing modules include the user interface, data updating procedures, program analysis, optimization routines, and the report generator. SAFEBRO manages both bridges and retaining walls.

Today SAFEBRO is being replaced with a Web-based management system called BaTMan (Bridge and Tunnel Management). BaTMan can be used for bridges and tunnels as well as for other structures. BaTMan is also available for other types of asset managers, such as rail administrations, subway administrations, municipalities, etc. Databases in BaTMan are linked to other systems, including a traffic database and a system for permissions for heavy vehicles.

Table 38. SAFEBRO organization.

Object Database	Knowledge Basis	Processing Modules
Administration	Measuring methods	Inspection
Maintenance	Condition development	Planning object
Technical design	Technical solutions	Planning bridge stock
Trafficability	Unit prices	Procurement
Damage		Verification
Planned action		Result analysis
Performed action		Load-bearing classification
Traffic flow		Exceptional convoys

Users

BMS data are updated as changes occur because of modification or new construction of bridges. Bridge engineers at the local road authorities enter the data. Databases in SAFEBRO are not linked to other databases or management systems. In the future, an asset management system will coordinate other object-specific systems.

Condition Data

Defects in bridges are reported in terms of physical, functional, and economic condition. Physical condition is stated both as method of measurement and measured value. The method of measurement is determined by type of damage, structural element, material, and other considerations (e.g., mode of action of element). Physical condition is described using the measurement variable appropriate to the method of measurement. The rating scale for functional condition is 0 to 3, with 3 being the worst condition. The rating for functional condition indicates the time until the defect is expected to impair the service of the bridge.

Table 39. Swedish condition ratings.

Rating	Physical Condition	Functional Condition
3	Repair needed now	Service impaired now, at time of inspection
2	Repair within 3 years	Service impaired within 3 years
1	Repair within 10 years	Service impaired within 10 years
0	Repair beyond 10 years	Service greater than 10 years

Economic condition indicates the extent of damage and the quantity of needed repairs. Economic condition is computed as defect quantity times average unit cost for repair, but this is not an estimate of actual project costs since project scope may differ from defect quantity. Greater economic condition values, however, correctly indicate more severe and extensive defects.

Beyond condition ratings, SAFEBRO stores data on each defect that includes the structural element affected, its material, the type of defect, the method of measurement of the extent of defect, and the measurement variable. The measurement variable is the basis for quantifying the growth of the defect.

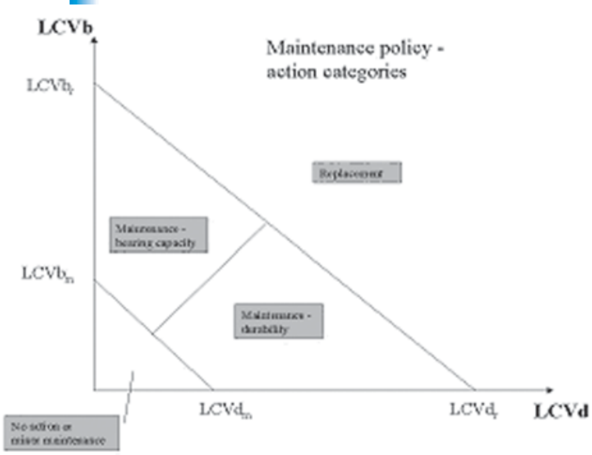


Figure 39. Decision space for repair versus replacement.

Prioritization

Repair priorities are established by defect severity, defect quantity, and economic condition of defects. Economic condition is used to compute the lack of capital value (LCV) for a bridge. LCV is the sum of the economic conditions of all defects at a bridge expressed as a fraction of replacement value. LCV is used to determine whether repair or replacement is appropriate for a bridge. In these decisions, LCV is first separated into two parts: LCVb, the lack of capital value related to load capacity of the structure, and LCVd, the lack of capital value related to durability.

To develop a network program for actions, repair or replacement projects are developed for each structure. Project planning includes the actions to apply, project schedule, impacts on traffic operations, improvements to capacity, and improvements to durability. Projects are evaluated under each of four strategies (see table 40).

Table 40. Swedish repair strategies.

Strategy	Description
A1	A project to minimize agency costs (lowest contract costs for repairs)
A4	A 4-year delay in the project to minimize agency costs
B1	A project to minimize user costs (least traffic delays, detour length, etc.)
B4	A 4-year delay in the project to minimize user costs

These alternative projects are aggregated in the formation of a network program plan. In this selection process, budget limits may be imposed, and coordination among bridge and road projects may be achieved. The selection is directed by two steering parameters. The first, trafficability, recognizes deck width and load capacity. The second, durability, recognizes remaining service life and lack of capital value. Network planning also considers ongoing costs to maintain network condition, the dependence of average conditions on budget level, the impact on users of changes in network condition, and the distribution of funds among local road agencies.

Maintenance program planning uses a 12-year horizon. Funding is annual, and actual work plans follow a 3-year cycle. Sweden uses PlanOpt, a system developed by Cambridge Systematics, to aggregate project-level requirements into network-level maintenance programs.

Deterioration Model

Deterioration models consider structures in groupings determined by age and structural type. Deterioration is forecast as a continuing loss in capital value. The general form is

$$LCV = a_0 + a_1 e^{rt} \qquad \textbf{Eq. 3}$$

LCV = Lack of capital value.
t = time.
a0, a1, r = parameters of the model.

Parameters a0, a1, and r are specified by the user, or calibrated to historical trends in loss of capital value. This exponential model can represent both accelerating and decelerating change in capital value.

Bridge Inspection

Sweden has four levels of routine inspections: regular, superficial, general, and major. Regular inspections are frequent, quick visits to bridges to detect significant new conditions. Regular inspections are performed by maintenance contractors. Superficial inspections, also performed by maintenance contractors, are made twice a year to verify that contract maintenance requirements are being met. General inspections are made every 3 years by trained inspectors from SNRA staff or consultants. During general inspections, SNRA verifies the actions of maintenance contractors, tracks the growth of known defects, and evaluates significant new conditions, if any. General inspections also examine electrical, hydraulic, or other bridge equipment. Major inspections are made every 6 years by trained inspectors from SNRA staff or consultants. Major inspections are complete examinations reporting all conditions and noting all defects in bridges. Major inspections include underwater inspection. Major inspections are the basis for specification of requirements for continuing maintenance.

In addition, SNRA performs special inspections of particular defects or deterioration mechanisms. Special inspections often involve testing methods such as ultrasound, radiography, etc.

Table 41. Swedish bridge inspections.

Inspection	Goal	Performed by	Inspector Training
Regular (frequent)	Detect severe damage.	Maintenance contractor	No special qualifications
Superficial (every 6 months)	Confirm maintenance actions.	Maintenance contractor	Good knowledge of maintenance requirements
General (every 3 years)	Monitor known defects. Verify performance of maintenance contractor.	SNRA staff or engineering consultant	SNRA-trained bridge inspector
Major (every 6 years)	Detect and evaluate defects in all parts of the structure. Verify performance of maintenance contractor. Inspect mechanical or electrical equipment, if present.	SNRA staff or engineering consultant	SNRA-trained bridge inspector
Special (as needed)	Make quantitative assessment of defects.	SNRA engineering consultant	Personnel with expertise in specific testing methods
Equipment (every 3 years)	Inspect mechanical and electrical equipment of the bridge.	SNRA staff or engineering consultant	Knowledge of hydraulic systems and other mechanical installations. Knowledge of the Swedish Electrical Installations Ordinance.

Inspector Training

Personnel performing general or major inspections must hold an engineering degree, have experience with bridge design and construction, and must complete a 1-week training course offered by SNRA. Inspectors must have knowledge of bridge types, bridge design specifications, defect types, and likely growth rates of defects.

Additional certification is needed for underwater inspection, and inspection of mechanical and electrical equipment. Quality assurance in bridge inspections is achieved by adequate training of inspectors, and by the use, where possible, of quantitative measures of damage.

Budgets for Inspections

Inspections are funded at $1.1 million a year. About half of the inspections are done by SNRA, and half by consultants.

NDT and Other Testing

NDT methods are used as needed to diagnose defects in bridges. Some inspections are invasive. When deterioration is found at deck surfaces, inspectors may open a window in the wearing course and waterproofing to examine the concrete deck. Windows are 500 mm by 500 mm. Concrete cores may be removed at windows.

Major inspections may include elevation measurements at survey pegs. Pegs are installed during construction on most substructures and many bridge beams. Peg elevations are recorded on as-built plans. Later measurements can reveal settlement.

Automated scour monitoring is employed at some structures. Monitoring systems are connected to alarms.

Long-Term Monitoring

Long-term monitoring is used both to track known defects and verify the performance of structures. Sweden offers several examples.

At Källösund Bridge, extensometers are used to monitor crack openings in the bottom flange of a concrete box girder bridge. Data collection is automated. The system can signal an alarm if a crack opening becomes too great. At Gröndals Bridge and Alsviks Bridge, crack opening measurements are used to verify that strengthening projects at these bridges are effective. At Forsmo Bridge, strain gages are used in an investigation of the impact factor for this railway bridge built in 1912. In two new bridges, Årsta and Svinesund, strain gages and extensometers are used to monitoring static and dynamic response.

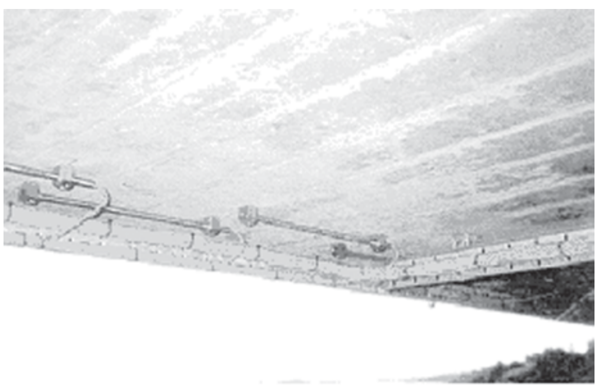


Figure 40. Källösund Bridge

Figure 41. Forsmo Bridge.

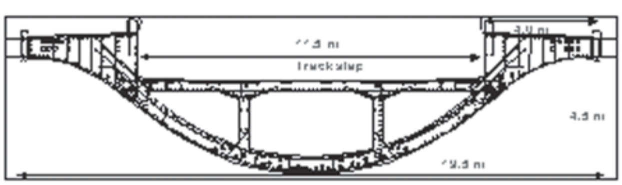


Figure 42. Årsta Bridge.

Figure 43. Svinesund Bridge.

Operations

Loads

Five vehicle-equivalent loadings are used to evaluate load capacity of bridges. An example, pattern 1, is shown in figure 44.

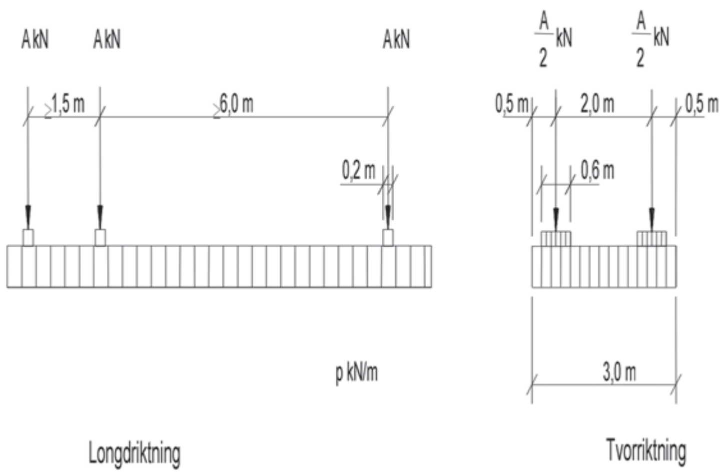


Figure 44. Load pattern 1.

Loads in this pattern are applied in multiple lanes. Axle loads, A, differ for simultaneous application in multiple lanes. Notice that the heavy vehicle, Lane 1, weighs 169 kips. The distributed load applied simultaneously in Lane 1 is 820 lbs/ft.

Table 42. Swedish design load pattern 1.

Lane 1 A = 250 kN P = 12 kN/m	Lane 2 A = 170 kN P = 9 kN/m	Lane 3 to x A = 0 kN P = 6 kN/m

Permit Loads

Permits are required for vehicles with gross weight greater than 600 kN (135 kips), width greater than 2.6 m (8.5 ft), or height greater than 4.5m (14.8ft). The heaviest (routine) permit vehicle has three axles, each bearing 325 kN (gross weight is 219 kips). Vehicles of this type must cross bridges singly. There are no designated routes for abnormal loads.

Sweden uses an automated system, called DISA, for permit administration.

Maintenance

All maintenance is done by maintenance contractors. SNRA's own maintenance group is one of the contractors and does more than 60 percent of the work. Each contractor is awarded a section of roadway. Each contract entails 750 to 1,500 km (465 to 930 mi) of road, with 50 to 100 bridges. Contract duration is 3 to 6 years. Maintenance contracts specify the performance that must be maintained in assets. SNRA specifies contract performance by identifying the elements to maintain, specifying the basis of performance measurement, and naming the permissible values of this measure. Maintenance contractors function within these specifications, and SNRA verifies adequate contract execution through inspections.

As an example, bridge railings must have adequate anchorage to bridge decks or edge beams. The method of measurement and the tolerable exposure of anchor bolts are specified. Performance specification includes what to check, how to measure (for anchor bolts, use a folding ruler), and how to maintain.

Maintenance contract requirements go further. Contracts require actions that include coating/sealing of edge beams, spot painting, parapet repairs, replacement of joint seals, water cleaning of decks, clearing of drains, and rehabilitation of erosion protection.

Figure 45. Measurement and maintenance of bridge railing.

Maintenance Budget

Sweden's annual budget is $60 million for maintenance, $90 million for new construction, and $20 million for rehabilitation and improvement of existing structures. The research and development budget is $1.8 million. Of the $60 million in maintenance, $6 million is for preventive maintenance.

Findings in Sweden

BMS

Maintenance programming. Sweden examines project alternatives to minimize agency costs and user costs. Costs of alternatives are further studied for their sensitivity to deferred implementation.

Lack of capital value. Bridge condition in Sweden is expressed as cost. In particular, defects are expressed as the costs needed for their remedy. This is a lack of capital value.

Inspection

Inspection interval and level. Sweden has four levels of routine inspection: regular (frequent), superficial (twice a year), general (every 3 years), and major (every 6 years). General and major inspections are conducted by experienced bridge engineers trained by SNRA.

Maintenance

Maintenance manuals. Sweden has specifications for maintenance contractors that identify the appropriate methods for measurement, evaluation, and repair of defects.

Washing. Sweden washes bridges and removes debris as a part of routine maintenance.

Operations

Warning system. Sweden has warning systems on some bridges to detect failures.

Maintenance

Knowledge basis for repairs. Common repairs for common defects are kept in the SAFEBRO knowledge database.

SWITZERLAND

Administration

Bundesamt für Strassen (FEDRO), the Swiss Federal Roads Office, administers 1,800 km (1,100 mi) of main routes called Swiss National Roads in a network of 71,200 km (44,200 mi) of Swiss roads. FEDRO is organized into two regions: Midlands (plateau) and Mountains (Alps and Jura). FEDRO works cooperatively with cantonal roads agencies for construction, maintenance, and repairs of pavements and bridges on the national roads. Cantons are responsible for inspection and design of bridges. Cantonal road agencies follow FEDRO specifications, and must seek detailed review of projects to gain FEDRO participation in funding.

The Swiss national roads network is valued at CHF55 billion (US$40.6 billion). Roads construction is funded by a motor fuel tax. Nearly two-thirds of the price of fuel is tax.

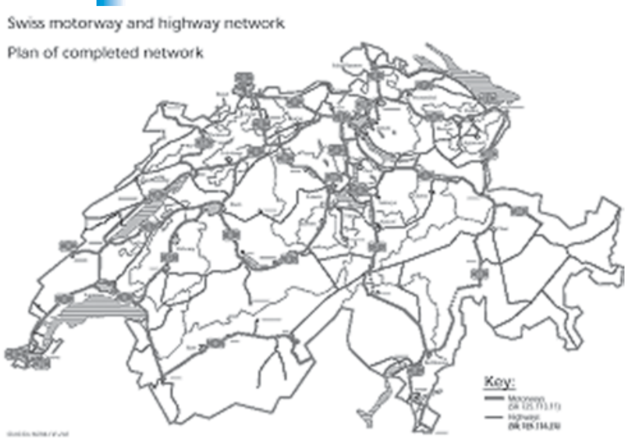


Figure 46. Swiss National Roads network. (FEDRO 2004)

Bridge Inventory

Spans of 5 m (16.4 ft) or more are bridges in Switzerland. The national roads have 3,380 bridges, with a total length of 270 km (168 mi), total deck area of 4.4 million m^2 (47 million ft^2), and a capital value of $8.5 billion. Swiss bridge design seeks durable structures. Joints and bearings are eliminated in most bridges less than 80 m (262 ft) in total length.

The motor fuel tax is EUR0.3 a liter ($1.25 a gallon). This generates $2 billion annually for roads. With this revenue, new Swiss national roads are fully paid at the time of construction. Highways are not funded by bonding or other borrowing. Maintenance funding is $350 million per year for Swiss National Roads. Of this, $140 million are allocated to roads structures. The target for the maintenance budget is 1.5 percent of the replacement value of assets.

Bridge Management

FEDRO uses KUBA software for bridge management. KUBA's database includes bridges, retaining walls, and protective structures. It has two main modules. KUBA-DB is the database, user interface, and report generator. Bridges can be accessed by identification number, location, route, or from an interactive map. Structural drawings are imbedded in the database. KUBA's database contains inventory data, inspection data, and data on completed repair projects. KUBA-DB supports several modes of interface. The structures mode is organized around inventory, inspection, and repair data. The parties mode identifies organizations involved with a structure, and coordinates communication among them. The transports mode provides evaluation of routes for permit loads. The reporting mode generates predefined reports. The administration mode is for information technology personnel.

KUBA-MS is the set of management functions. KUBA-MS provides economic optimization of maintenance programs. KUBA-MS is the knowledge database containing catalogues of types of structures, elements, and defects. Maintenance and repair actions link to elements and defects. Deterioration models expressed as Markov matrices (Markov matrizen fur verfall) are incorporated for groups of elements and environments.

KUBA-MS uses an element-level optimization. Two strategies are generated: least long-term cost and least short- term action (which correlates with least traffic interruption). A 10-year plan is routinely generated.

KUBA-DB and KUBA-MS are separate, stand-alone systems. A data import from DB to MS is performed in advance of an optimization analysis.

FEDRO also uses UPlaNS, an asset management system that handles pavements, bridges, equipment, and accessories. UPlaNS provides maintenance planning along route corridors, jointly optimizing both pavement and structures maintenance. UPlaNS operates on a database that contains common inventory data, condition data (the UPlaNS inspection module provides a tablet portable computer interface), and work data, both planned and completed. UPlaNS aggregates maintenance projects for pavements and structures in 15-km (9-mi) segments of routes.

Development of UPlaNS began in 1999. FEDRO lists the goals for UPlaNS:

- Seek a balance between agency costs and user costs.
- Provide integrated planning for pavements and structures, and also for maintenance projects and new construction.
- Prepare programs about 6 years in advance, allowing sufficient time to collect data, define road sections for maintenance, detail all coordinated projects, and award contracts.
- Centralize project planning in FEDRO, yet continue a close collaboration with cantons.

UPlaNS seeks a nationwide coordination of work to provide 26 years of maintenance-free operation in each route segment, avoid simultaneous work in segments less than 50 km (31 mi) apart, and minimize the impacts on traffic.

Innovation

The scan team visited the Institut de Structures, Ecole Polytechnique Federale de Lausanne (EPFL), the Structural Engineering Institute of the Swiss Federal Institute of Technology, to view bridge-related research. Projects in the structural concrete, composite construction, steel structures, and maintenance and safety of structures laboratories were discussed.

Thomas Keller presented work on prefabricated FRP deck sections made composite with steel beams. The preferred shear connection is a glued interface. Temporary installations can be made with bolted connections. Manfred Hirt presented an evaluation of joints in tubular-section steel truss bridges (figure 47). Emmanuel Denarie reported on high-performance concrete. EPFL is studying the use of a very low permeability concrete applied as a skin on larger concrete members. Bryan Adey reported on impact-echo testing and on modeling of chloride-induced corrosion of concrete reinforcing steel.

Figure 47. Dattwil Bridge. (EPFL 2004)

EPFL researchers report a good correlation between permeability of in-service concrete members and their durability. EPFL works extensively with the Torrent permeability meter to identify concrete quality as good, fair, or poor.

The Torrent meter uses surface airflow under vacuum and a correction for concrete moisture to yield a measure of concrete permeability. Permeability is a key factor in transport of water-borne contaminants into concrete.

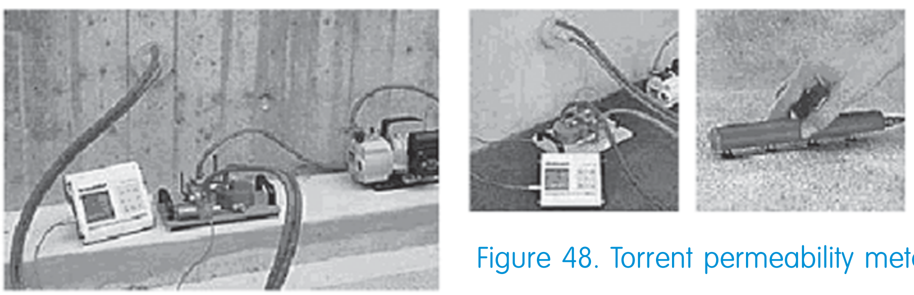


Figure 48. Torrent permeability meter. (Proceq USA 2004)

Bridge Inspection

Bridge inspections are performed by cantons, either directly by road agency staff or by consultants. Cantons must conduct a visual inspection of bridges every 5 years. Conditions of all components are reported and all defects are noted. The canton develops recommendations for repairs, which FEDRO reviews. FEDRO review considers the defects and the proposed remedy, its permanence, the urgency of repair, impacts on traffic, and project costs. Projects are finalized in a collaborative effort between FEDRO and the cantons.

Operations

Nominal loads have increased from 28 t to 40 t (62 kips to 88 kips) to meet the new Eurocode 1 requirements.

Permit Load Routing

KUBA bridge management system provides routings for permit loads. Bridge capacities are stored in the database.

Maintenance

Swiss FEDRO is working on a zero-maintenance concept for maintenance programming. On a project level, the Swiss effort seeks technologies that improve bridge durability, allowing longer intervals between repair projects. On the network level, Swiss maintenance planning is coordinated to minimize impacts on traffic operations.

The Swiss program UPlaNS supports improved maintenance planning of the Swiss National Roads. The network of about 1,800 km of national roads is divided into maintenance sections. Maintenance planning and execution is constrained to accomplish the following:

- The minimum distance between two maintenance sections with traffic restrictions is 50 km.
- The maximum length of a maintenance section is 15 km.
- The minimum maintenance-free period for each section is 5 to 25 years (20 years on average).

A maintenance project, when executed, must address all needs in both roads and structures in the section, and must prepare the section for a 20-year period of maintenance-free operation.

It is essential that components remain without defects during their planned service duration, or the potential advantages of proactive renewal are lost. This requires good materials, good construction practice, and good quality control. It also requires a full understanding of the need for superior resistance in specific areas of bridges. In Switzerland, engineers note the aggressive condition at standing salty water (Standwasser) and from traffic spray (Spritzwasser).

FEDRO expects most bridges to require repair projects every 25 years. For the Swiss national roads network, this means about 200 repair projects each construction season, and substantial impacts on traffic operations. New roads and bridges may be constructed with complete, additional lanes intended for emergency use in normal situations that can be converted to traffic lanes during repairs.

Findings in Switzerland

BMS

UplaNS. The Swiss have developed a corridor-based asset management system called UPlaNS.

Zero maintenance/proactive renewal. The Swiss plan for scheduled replacement for roads and structures can maximize traffic function because all closures, detours, etc., are known years in advance. The approach demands the construction of roads that will have all of the service life planned, and that the renewal of roads (and the replacement of bridges) must occur as scheduled.

Inspection

Torrent meter. Swiss researchers report good experience with the use of the Torrent meter to evaluate permeability (and therefore durability) of concrete for in-service bridges.

Maintenance

Impermeable, ductile concrete. Swiss research is developing special concretes that are water-impermeable and crack resistant. These are used as a (thick) coating or skin at the surface of concrete elements.

UNITED KINGDOM

U.K. Highways Agency

The U.K. Highways Agency (HA) has a network of 9,400 km (5,840 mi) of trunk roads that link major population centers, major ports, and key cross-border routes. The network has about 10,000 bridges and 6,000 other structures (tunnels, retaining walls, and sign structures). The overall asset value of the HA network, including road pavements, structures, earthworks, signing, lighting, etc., is estimated at about £65 billion (US$100 billion). Local authorities have responsibility for some 100,000 other bridges and structures. The United Kingdom has about 155,000 bridges on roadways, waterways, and rails.

HA's budget in 2001 was £672 million (US$1.06 billion) for maintenance and £494 million

US($779 million) for improvements. The internal administrative budget is £77 million (US $121 million).

Figure 49. U.K. Highways Agency network. (Highways Agency 2004)

HA has a staff of 1,700 people involved in developing guides and specifications, and administering contracts. HA develops the policies for the entire life cycle of bridges, including construction, inspection, maintenance, and improvement. The direct tasks of construction, maintenance, inspection, etc., are performed by contractors under HA oversight. Over the next 2 years, HA will recruit about 600 traffic officers to handle traffic management duties previously performed by police.

More information on HA is available at www.highways.gov.uk.

Transport Research Laboratory

The scan team visited the Transport Research Lab (TRL) in Crowthorne. TRL is the largest U.K. center for transportation research. TRL has 500 staff and 1999 billings of £33 million (US$52 million). TRL recently completed a project examining the feasibility of a bridge management system for Europe (BRIME 2002). The project provides an extensive review of existing management practices in the participating countries. The BRIME report is online at www.trl.co.uk/brime/index.htm.

Bridge Inventory

In the United Kingdom, it is a bridge if its span is at least 1.8 m (5.9 ft). About 80 percent of Highways Agency bridges are concrete, 15 percent are steel, and 5 percent are other materials, including many masonry arches.

Figure 50. Waterloo Bridge. (Highways Agency 2003)

The HA focus is on improving its bridges. U.K. bridges were designed for a 20-t (44-kip) nominal vehicle before the 1960s, and a 38-t (84-kip) vehicle from then until the 1980s. Integration with the European Union required that U.K. highways admit 40-t (88-kip) vehicles. HA efforts have been devoted to improving older bridges built for lower loads. HA has also managed a population of prestressed concrete bridges weakened by corrosion and breakage of tendons. These problems had their origins in poor grouting and ineffective waterproofing, and were at their worst in older bridges. The significant reductions in load capacity at some bridges have been a direct challenge for HA.

Bridge Management System

HA has a structure management information system (SMIS). The name is literal. The system manages information. SMIS is the database that underlies the user interface and processing modules for bridge management. SMIS keeps separate databases for England, Wales, Scotland, and Northern Ireland. SMIS employs component-level models for structures. Each structure exists as a collection of components.

Table 43. U.K. BMS modules.

Module	Project Level	Network Level
Inventory	Route management	Queries, design feedback, maintenance feed-back
Condition	Predict future condition, Residual life	Defect frequency, Rate of deterioration
Assessment	Critical sectors/elements, Reserves of strength	Number of substandard bridges
Maintenance	Feasible maintenance options, Optional maintenance program	Effect of maintenance on condition, costs (engineering and traffic delay)
Prioritization	Consequences of deferring maintenance	Dealing with backlog

Working with SMIS are modules for common BMS functions, such as control of inventory data, deterioration modeling, assessment of maintenance needs and costs, and evaluation of maintenance priorities. Each module has a role in project-level decisions and network-level strategies.

The SMIS and the BMS modules both conform to the standards of the Electronic Governmental Interoperability Framework (eGIF). eGIF establishes common Internet protocols for access between governmental agencies and between the government and the public. (See Appendix D and http://www.govtalk.gov.uk/schemasstandards/egif.asp.)

Performance Measures/Indicators

HA employs performance indicators to track the status of the network. The network measures include the following:

- Number of bridges with weight restrictions
- Number of bridges with lane (geometric) restrictions
- Number of bridges with more than x elements in state 4
- Number of bridges with more than x elements in state 5
- Number of bridges with capacity indicator, k, value <1
- Number of principal inspections deferred

Performance indicators (PI) are being developed. These will include the following:

- Visual condition
- Reliability
- Availability
- Outstanding maintenance

Numerical values of performance indicators range from 100 (best) to 1. Visual condition PI is formed from condition ratings for defects. Visual PI is further modified by element importance (within the load path). Reliability PI responds to probability of failure and consequences of failure. Reliability PI includes recognition of current condition and the effect of condition on capacity. Consequences are disruption of traffic operations. Availability PI indicates existing traffic restrictions on the bridge. Outstanding maintenance PI indicates deferred maintenance at the structure.

Performance indicators are the basis for deterioration models. Models are formed for groups of components with similar maintenance actions. HA uses deterioration models for 60 groups of similar components. Deterioration models indicate a rate of change in a performance indicator and the range of its probable values over time. Each performance indicator has a desired lower bound, called a maintenance safety threshold. Deterioration models indicate the rate of threshold crossings.

An example is an indicator, k, for normalized load capacity (k=1 indicates a bridge rating equal to current load design standards). The deterioration model has a mean and a distribution of k values for a new bridge, and a mean and a range of rates of decrease in k. For this model, the maintenance safety threshold is 0.91.

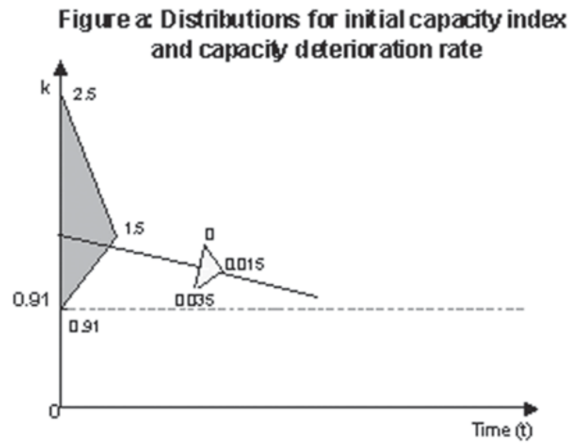


Figure 51. Deterioration in capacity index k.

Maintenance Programming and Prioritization.

Maintenance actions are first identified at the component level. These actions are assembled into projects. Next, a cost/benefit analysis is performed to identify which projects to execute. The projects are aggregated into a network plan. In this step, the coordination of structures projects and pavement projects is considered. HA makes final decisions on project funding.

Risk is considered in forming the network plan. Risk is unanticipated cost, either to the agency or to users. Risk reflects the possibility that new defects or rapid growth in existing defects will lead to reductions in service or increase in repair costs not expected in network planning. The HA process, called Highways Agency Risk Management (HARM), is discussed in HA publications *Value for Money Manual* (1996), and *Business Risk Management* (2003). The HARM process sets priorities from 1 to 4 for risk (avoidance) in four categories: safety, function, durability, and environment. Risk in each category is identified as persistent, transient, or accidental. Each structure has a vulnerability related to events (defect appearance or growth) that can impair the safety, function, etc., of the structure. The consequences are the impact on traffic operations, including delays, detour lengths, or reduced service to essential facilities such as hospitals. The user costs provide the measure of consequences. A synopsis of HARM can be found at www.highways.gov.uk/roads/projects/misc/risk_man/index.htm. Appendix E has an excerpt from the HARM document.

Bridge Inspection

General inspections occur every 2 years. Principal inspections occur every 6 years. Principal inspections are thorough visual examinations of all parts of bridges, reporting all conditions and noting all defects. Defect severity is reported on a 1-to-5 scale, and defect extent on an A-to-E scale. These condition ratings are used in SMIS to generate the performance indicator for visual condition.

Special inspections, often involving material sampling or NDT applications, occur as needed.

Inspections for HA's 10,000 bridges are performed by consulting engineers. Inspections for the 100,000 bridges controlled by local roads agencies are performed by local agency staff or consultants.

Manuals

HA has an extensive catalog of publications guiding bridge engineers. Table 46 is a table from the *Bridge Management in Europe* report.

Table 44. HA standards in the *Bridge Management in Europe* report.

STANDARDS—BRIDGES AND STRUCTURES (BD SERIES)	
BD 21/97	The Assessment of Highway Bridges and Structures Amendment No. 1
BD 34/90	Technical Requirements for the Assessment and Strengthening Programme for Highway Structures Stage 1—Older Short Span Bridges and Retaining Structures
BD 37/88	Loads for Highway Bridges
BD 44/95	The Assessment of Concrete Highway Bridges and Structures
BD 46/92	Technical Requirements for the Assessment and Strengthening Programme for Highway Structures Stage 2—Modern Short Span Bridges
BD 48/93	The Assessment and Strengthening of Highway Bridge Supports
BD 50/92	Technical Requirements for the Assessment and Strengthening Programme for Highway Structures Stage 3—Long Span Bridges
BD 56/96	The Assessment of Steel Highway Bridges and Structures
BD 61/96	The Assessment of Composite Highway Bridges
ADVICE NOTES—BRIDGES AND STRUCTURES (BA SERIES)	
BA 16/97	The Assessment of Highway Bridges and Structures Amendment No. 1
BA 34/90	Technical Requirements for the Assessment and Strengthening Programme for Highway Structures Stage 1—Older Short Span Bridges and Retaining Structures
BA 38/93	Assessment of the Fatigue Life of Corroded or Damaged Reinforcement Bars
BA 39/93	Assessment of Reinforced Concrete Half-Joints
BA 44/96	Assessment of Concrete Highway Bridges and Structures
BA 51/95	The Assessment of Concrete Structures Affected by Steel Corrosion
BA 52/94	The Assessment of Concrete Highway Structures Affected by Alkali-Silica Reaction
BA 54/94	Load Testing for Bridge Assessment
BA 56/96	The Assessment of Steel Highway Bridges and Structures
BA 61/96	The Assessment of Composite Highway Bridges
BA 79/98	The Management of Substandard Highway Structures

Figure 52. Ynysygwas Bridge.

NDT and Special Inspections

The Highways Agency and its research collaborator, the Transport Research Laboratory, have been engaged in an extensive study of conditions of tendons in prestressed concrete bridges. The study responds to problems with post-tensioned bridges that emerged in the 1970s. In the 1980s and ‘90s, more serious problems were uncovered and one bridge collapsed. In 1992, construction of prestressed bridges was halted and a special investigation program was undertaken.

The investigation was concerned first about the condition of internal tendons, and consequently about the right choice of methods to verify condition. A number of NDT methods were tried, including radar, radiography, impact echo, reflectometry, ultrasonics, magnetic tendon locator, and covermeter. Each method had some success, but none was entirely satisfactory or as effective as intrusive investigation.

Intrusive investigations are careful excavations to expose tendons to visual examination. Necessarily a local technique, excavations are made at critical points along the tension where grout may be deficient or water may accumulate.

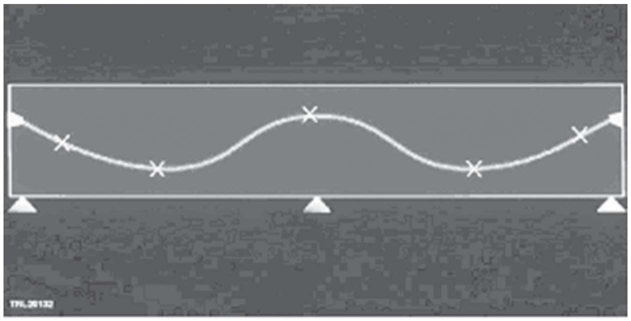


Figure 53. Tendon inspection at critical points.

Figure 54. Railway viaduct at Huntingdon.

One NDT technique, acoustic monitoring, proved useful for managing vulnerable bridges. Acoustic monitoring reveals (indeed records) the occurrence and location of new wire breaks in tendons. Monitoring must be continuous, since wire breaks are captured in real time only. Wire breaks that occur before monitoring are not revealed.

The system installed at the railway viaduct at Huntingdon was automated. An array of acoustic sensors on the bridge captured the sound of wire breaks, and by triangulation, indicated the position of the breaks. The bridge was in service and awaiting repair while the monitoring system was in use, and so the structure has many acoustic sources other than wire breaks. The system was able to discern the wire breaks. HA engineers were able to monitor the wire breaks, track the decline in load capacity, and continuously update their evaluation of the bridge's safety.

Operations

Loads

U.K. Construction and Use (C&U) regulations allow nominal trucks at 44 t, 40 t, and 32 t, with different numbers and capacity of axles (table 45). Permissible vehicle dimensions are height up to 4.3 m (14 ft), and length to 18.65 m (61 ft).

Table 45. U.K. nominal trucks.

Vehicle Gross Weight Metric ton (kip)	Axles	Greatest Axle Metric ton (kip)
44 (97)	6	10.5 (23)
40 (88)	5	11.5 (25)
32 (70)	4	19.0 (42)

Weigh-in-Motion

HA installed a weigh-in-motion (WIM) system at the Avonmouth Bridge to measure vehicle loads during an extensive strengthening project between 1995 and 2002. This was a complex system, linking WIM data with automated recognition of vehicle license plates. After completion of the project, a simpler system, supplied by Applied Traffic, was installed. Now data on vehicle weights are used in fatigue analysis for the bridge.

Permit Loads

Loads with gross weight greater than 50 t (110 kips) require a permit. Loads over 100 t (220 kips) require escort during transit (the escort may be an HA consultant). Loads as great as 150 t (330 kips) have passed on HA roads. Loads may be abnormal in weight or dimensions. Permit classifications recognize loads that are abnormal for dimensions (C&U permit) or for weight (Special Types General Order (STGO) permit). Extremely abnormal loads, for dimension or width, get a special order (SO) permit. C&U or STGO permits are issued routinely. SO permits are approved individually by HA. As a part of this approval, HA specifies the route that the SO load must follow. In most years, there are about 1 million C&U and STGO loads, and 500 SO loads. The Highways Agency is developing EDSAL, an Internet portal to administer abnormal loads. Completion is anticipated in 2005.

Division of loads is considered for all STGO permits. SO permit loads must be evaluated for their effect on traffic congestion. The (weakened) condition of structures on the route is considered, and nighttime transits may be required. Moreover, alternative transport by rail or water is considered before a SO permit is issued (Appendix F has information on the U.K. Inland Navigator).

Bridge Load Rating

In its BRIME report, TRL identifies five levels of bridge rating:

- Level 0—No formal assessment of load capacity.
- Level 1—Simple methods such as beam-line analysis.
- Level 2—Load effects refined, as by the use of three-dimensional analysis models.
- Level 3—Measured, bridge-specific data to define load/response relations for the structure and boundary conditions.
- Level 4—Partial factor load and resistance factor design (LRFD) methods.
- Level 5—Reliability assessment, explicit evaluation of the probability of failure considering the uncertainty in all aspects of loading, material, structural elements, and system response.

Load Rating for Deteriorating Structures

TRL has studied the effect of deterioration on load capacity of bridges. One example is an aging reinforced concrete viaduct at Chilwell. Losses in reinforcing steel were assumed, and continuing losses were monitored by corrosion electrical current. Deterioration was modeled variously as loss in rebar cross-section, concrete properties, steel properties, bond properties, and structural stiffness. Moment capacity is critical for the bridge. Moment capacity has a linear relation to loss in reinforcing steel, and therefore a linear relation to corrosion current.

Figure 55. Chilwell Viaduct.

Maintenance

HA administers maintenance for its network in 16 geographic regions. In each region, HA engineering consultants direct the work of maintenance contractors. As with inspections, the majority of the bridges and maintenance contracts are in the hands of local roads agencies.

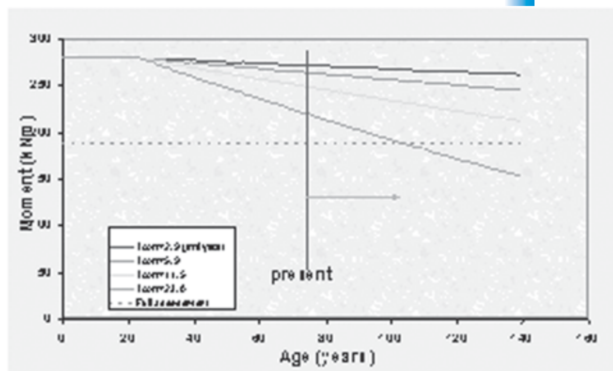


Figure 56. Loss of strength at Chilwell Viaduct.

BMS in Wales

In Wales, engineers recognize that increasing traffic volume and truck loads require the improvement or replacement of many bridges, regardless of their condition. This suggests that the steady state maintenance argument is flawed. A well-maintained bridge will not achieve its design life, because it will become obsolete, regardless of maintenance. Therefore, structures should be maintained only to achieve a residual life.

Wales proposes that a management system estimate the end of service, and not a value of condition. Maintenance and repair programs are adjusted to fit the expected service life of the structure and the certainty of its replacement. In this approach, transportation agencies manage deterioration, rather than bridges, completing sufficient repairs to maintain adequate safety and reasonable service.

This approach is familiar in pavement management, where a finite service life is recognized at the outset. Network maps report the condition of pavements by their remaining years of service.

Figure 57. Residual life of pavement.

Findings in the United Kingdom

BMS

Structures management. The United Kingdom maintenance management system includes tunnels and retaining walls as well as bridges.

Bids and prioritization system. The bids and prioritization system (BAPS) is a process for evaluating projects, including the (potential) user costs for delay in maintenance. BAPS is in development, and not yet implemented.

Risk-based programming. HA employs several measures of risk, and uses a scoring system to determine priorities for projects.

Deterioration model. Residual service life is determined as residual load-carrying capacity. There is a linear model for loss in load carrying capacity.

BRIME. TRL completed a large study of bridge management practices in Europe called the BRIME project.

Focus on bridge strength. Priorities for maintenance and forecasts for future needs focus strongly on bridge strength rather than visible conditions.

Performance indicators. HA has a framework of computed indicators of performance.

Data/file standards. Government intercommunications must satisfy common standards called eGIF.

Inspection

Inspection interval and type. HA requires general inspections every 2 years and principal inspections every 6 years.

Asset integrity HA is developing a knowledge-based determination of inspection frequency. Frequency is adapted to the evaluation of asset integrity.

NDT for prestressing tendons. Research and field testing in response to emerging problems with prestressing strands showed that NDT diagnostic techniques generally are not effective. Invasive inspection is effective, as well as acoustic monitoring (not diagnosis).

Inspector training/certification. There is no national standard for inspection training or certification.

Operations

Load rating. The United Kingdom went through a period of reevaluation and rehabilitation of structures to meet higher legal loads**.**

Load rating/structural analysis. BA 79 describes five levels of load assessment. These range from simple methods to reliability-based assessments.

Maintenance

Waterproofing. HA finds good performance with waterproofed decks and silane penetrating sealers. The United Kingdom does not use epoxy-coated reinforcing steel.

Condensed List of Findings

Topic	Topic Priority	Type of work	Overall Priority	Recommendation	Source Findings	Summary Table No.	Primary author and Initial contact
BMS	High	Follow-up	Unknown	Clarify corridor-based management.	25	Table 3	Friedland
	High	Follow-up	Unknown	Clarify UplaNS.	34, 46	n/a	Romack
	High	Study	High	Develop risk-based management, including consideration of serviceability. NCHRP project.	19, 84	Table 13	Shepard
	High	Implementation	High	Promote the concept of an integrated engineered structures management approach (bridge, walls, sign structures, etc.).		Table 6	Hearn
	High	Synthesis	High for some agencies	Investigate management plans for special structures. Study and compare to Florida.	14, 22	Table 4	Romack
	High	Synthesis	Medium	Report/disseminate design for inspection and maintenance. (See operations recommendation as well.)	30	Table 5	Combined
	Medium	Study	Underway by FHWA	NCHRP study. Feasibility plan for U.S. reference bridges.	5	n/a	Friedland
	Medium	Study	Medium	NCHRP project on "no-surprise" maintenance.	39	Table 10	Hearn
	Medium	Synthesis	Medium	Compare with U.S. manuals for condition reporting, bridge maintenance.	8	Table 14	Thompson
	Medium	Synthesis	Medium	Report on asset valuation practices.	23, 27, 45, 87	Table 6	Shepard
	Medium	Synthesis	Medium	Report/disseminate performance indicators. Synthesis.	91, 70, 71	Table 2	Romack
Inspection	High	Study	High	Develop an inspection-frequency plan based on a rational approach including condition, structure type, etc. Would include a tiered inspection type.	3, 21, 69, 72, 85, 95	Table 7	Everett

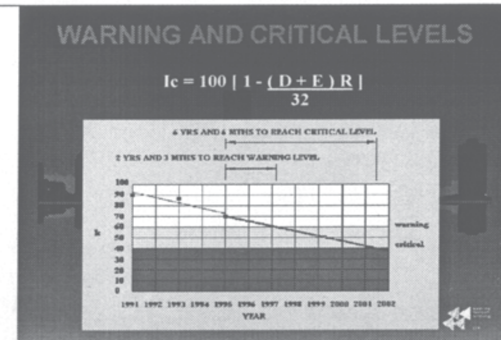
Topic	Topic Priority	Type of work	Overall Priority	Recommendation	Source Findings	Summary Table No.	Primary author and Initial contact
	High	Study	Tied to Frequency	Investigate inspector qualifications, including modular training to match structure types, recertification, recalibration, QC/QA, mentoring program, and minimal physical qualifications.	2, 4, 10, 15, 21, 29, 53, 75	Table 8	Everett
	Low	Follow-up	Low	Create a task group to assemble, review, and capture new and/or innovative ideas in the various inspection manuals.	67	Table 14	Hearn
	Medium	Study	High	Investigate the use of Torrent concrete permeability testing on U.S. decks/slabs.	99	Table 16	Hurst
Operations	High	Follow-up	Medium	Obtain and assess technologies and approaches for repair.	7, 9, 30, 35, 40, 54, 8 1,89	Table 17	Puckett
	High	Study	High	Assess the use of waterproofing systems for decks and substructures within the United States, and develop a guide for recommended practice.	92	Table 9	Shepard
	High	Synthesis	High	Obtain and assess information from scan countries and the United States on standardized practices for bridge repair techniques. Initiate NCHRP project to create nationally applicable best practices manual for bridge repair.	7, 9, 35	Table 5	Young
	High	Study	Medium	Promote the use of bridge WIM as a screening tool for overweight vehicles.	60	Table 15	Christian
	High	Synthesis	High	Define and promote specific approaches to incorporate inspectability and maintainability in the design process. Create a best practices manual, Web site, etc.	30	Table 5	Friedland
	Low	Research	Low	Monitor progress on identified unique research that may have applicability in the United States.	48	n/a	Hearn
	Low	Synthesis	Low	Review U.S. practice for use of standardized load testing/rating trucks and systems.	52	Table 12	Thompson
	Medium	Implementation	Medium	Promote best practices maintenance approaches, such as bridge washing, in coordination with inspections.	12	Table 10	Christian

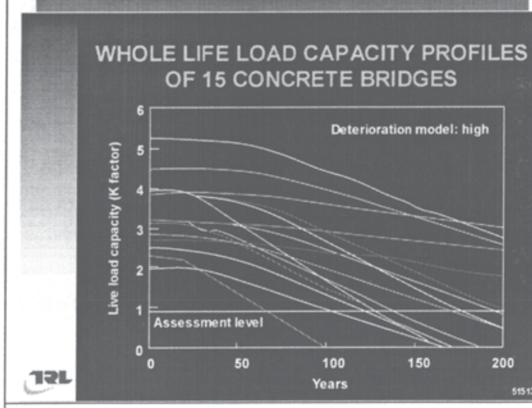
Topic	Topic Priority	Type of work	Overall Priority	Recommendation	Source Findings	Summary Table No.	Primary author and Initial contact
	Medium	Synthesis	High for some agencies	Assess and promote the use of simple bridge integrity monitoring/warning systems for extreme events (e.g., vessel collision).	17	Table 11	Puckett

Finding 1—Performance Measures

<table>
<tr><td colspan="2">Bridge Preservation and Maintenance in Europe and South Africa
International Technology Scanning Program
March 28 to April 13, 2003</td></tr>
<tr><td colspan="2">Denmark, Finland, France, Germany, Norway, South Africa, Sweden, Switzerland, United Kingdom</td></tr>
<tr><td>Recommendation</td><td>Initiate an action to further study performance indicators used in the bridge management system.</td></tr>
<tr><td>Brief Description</td><td>Several countries use bridge performance measures to assist in managing their bridge inventory and targeting scarce resources.</td></tr>
<tr><td>Reference Countries</td><td>United Kingdom and South Africa</td></tr>
<tr><td>Elaboration and Figures</td><td>
The English bridge management system includes structural performance indicators to provide decisionmakers numerical representation of asset performance and needs. A variety of performance indicators (PI) have been developed, including a structural PI, management PI, reliability PI, condition PI, safety PI, and asset value PI. Others are being considered, such as an efficiency PI. The existing PIs are simple, consistent among authorities, based on existing data, and used to predict future variations. A 0-to-100 index is computed, factoring in probability of failure, reserved capacity, and critical element condition.

In South Africa, elements of the structure are rated separately, taking into account the degree (D), extent (E), and relevancy (R) of a defect. The DER rating system ranges from 1 to 4, with 1 being a minor defect localized with minimum importance, and 4 being a severe defect generally with critical importance. Each deck, pier, abutment, and wing wall is assessed separately using the rating system, as are bearings, parapets/balustrades, and bridge joints. Other items rated using the DER rating system include embankments, guardrails, waterway, drainage, and pier protection. The South African National Road Agency has developed an algorithm to combine the rating system findings. The algorithm in the BMS program computes a condition index, priority index, functional index, and weighted overall priority index. The bridges are then ranked in order.



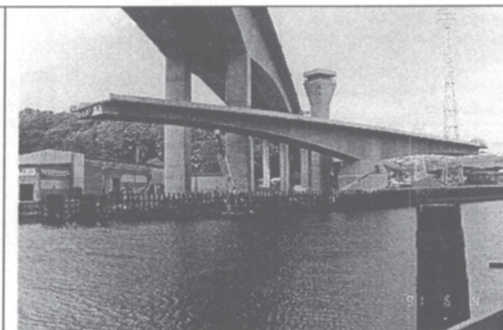


</td></tr>
<tr><td>Significance to Bridge/Structure Preservation and Maintenance</td><td>A method to provide management officials and decisionmakers with a numerical snapshot of performance of structures and priorities would be useful in the United States. States now rely primarily on the National Bridge Index sufficiency rating (SR) for establishing their bridge program. Some are incorporating the Pontis® health index into their evaluation process. The SR does not provide a clear distinction of structure performance or needs because all factors affecting the situation are combined into this one index. FHWA, in cooperation with AASHTO, has studied this problem, but the highway bridge community did <u>not</u> readily accept the alternatives produced.</td></tr>
<tr><td>Suggested Actions</td><td></td></tr>
<tr><td>References</td><td></td></tr>
</table>

Finding 2—Corridor-Based Management

Bridge Preservation and Maintenance in Europe and South Africa International Technology Scanning Program March 28 to April 13, 2003	
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom	
Recommendation	Evaluate and promote corridor-based management principles for bridge preservation and project decisions.
Brief Description	The scanning team learned of techniques being developed in two countries to apply management principles of asset management to the bridge management system. It was described as a corridor management approach to bridge preservation and project needs.
Reference Countries	Finland and Switzerland
Elaboration and Figures	Finland is developing a network-level management system called Hibris, which will analyze and evaluate bridge and pavement needs in an integrated environment. It is composed of the existing Highway Investment Programming System and the Verkko-Siha, the equivalent system for bridges. The system will be capable of optimizing actions, using budget data and Markovian models, for both pavement and bridges. Performance and planning indicators, including a repair index and a rehabilitation index, will be developed for the system. Life cycle cost analysis principles will be used to determine the remaining service life of bridges and pavements. A separate model will be developed for concrete bridges. Repair and rehabilitation indexes and life cycle costs analysis are computed in the project-level BMS. Switzerland has designed a system based on asset management principles and will be awarding a contract in 2003 to develop the system. The Swiss now use a bridge management system called KUBA, which is a hybrid of the U.S. Pontis system. Several years ago, they developed a pavement management system called U-Plans. Under this new system, a corridor management approach will be initiated to provide management tools for planning actions on highway assets, including pavements, structures, electromechanical, and accessories. U-Plans will allow managers to optimize actions on assets systemwide or on a corridor or section of the highway facility.
Significance to Bridge/Structure Preservation and Maintenance	For the most part, bridge management systems in the United States operate independently of other systems. Activity is underway to integrate management systems for efficiency in data collection and storage. Not much has been done in the way of combining assets into a systemwide or corridor management approach. This certainly is an area that needs development because decisions should be made considering the needs of more than just one asset.
Suggested Actions	Evaluate details of the corridor management approach for highway assets in Finland and Switzerland.
References	Research papers from Finland and Switzerland.

Finding 3—BMS for Special Structures

Bridge Preservation and Maintenance in Europe and South Africa **International Technology Scanning Program** **March 28 to April 13, 2003**	
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom	
Recommendation	Evaluate and promote management systems for special structures or structural types.
Brief Description	The scanning team learned of techniques that have been developed or are being developed in several countries to manage unique or special structures.
Reference Countries	Denmark and Sweden
Elaboration and Figures	Denmark is developing systems management for special structures, such as cable-stayed bridges or those with unique features. The system will include several modules to provide guidance for inspecting, maintaining, and operating the structure. The modules will include the objectives and strategies, personnel requirements to manage the structure, inventory for establishing elements and procedures for documentation, traffic operations to guide operating and planning for restrictions, manual for technical operations describing installations and maintaining an event log, information on different inspection types (principle, special, detailed) and maintenance options with management techniques for measuring and tracking performance, and guidance on management of equipment and materials. Sweden has assembled a library of best repair practices for maintaining and repairing special structures and other structural types. These have been included in a knowledge-based system as part of the bridge management system, allowing the user to access this information to select an effective treatment for a particular situation. 
Significance to Bridge/Structure Preservation and Maintenance	For the most part, bridge management systems in the United States do not include all of the elements of special structures, or a best practices database containing maintenance or repair details for the system user. In some States, contract documents require the consultant to prepare a maintenance and operations manual for special or unique structures. Also, States do have reference manuals for bridge maintenance and repair of specific elements, including FHWA's National Highway Institute Bridge Maintenance Training Course reference manual. The ongoing efforts in Denmark and Sweden may have potential for improving the management of unique or special structures in the United States.
Suggested Actions	Evaluate the details of the special structures program in Denmark and the application of a knowledge-based repair system such as the one in Sweden. Review and evaluate the management program being implemented for movable span bridges in Florida.
References	Notes from presentations and discussions. Research papers from Denmark and Sweden.

Finding 4—Best Practices Manual

	Bridge Preservation and Maintenance in Europe and South Africa International Technology Scanning Program March 28 to April 13, 2003
	South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom
Recommendation	Obtain and assess information from scan countries and the United States on standardized practices on bridge preservation and repair techniques; initiate NCHRP project to create nationally applicable best practices manual for bridge preservation and repair.
Brief Description	
Reference Countries	South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, and United Kingdom
Elaboration and Figures	In South Africa, a visual inspection manual provides guidance in bridge inspections. Inspections include identifying an associated remedial work activity for noted details. Repairs are grouped for several bridges in an area or linked to roadway projects to reduce costs. The Swiss report a "zero maintenance," or perhaps a more properly described "no-surprise maintenance," concept being implemented in teaching/classes. Swiss bridge management programs KUBA-MA-Ticino and KUBA–DB include a knowledge base with catalogues of types of structures and elements, as well as damage catalogues and catalogues of maintenance actions (documentation for these is available in German and French). The French have a manual that compiles a menu of concrete repair options. German design guidance manuals consider constructibility, maintainability, and ease of inspection. German DIN 1076 provides guidance for engineered structures on roads. Denmark clearly defined maintenance. Maintenance contracts are shared with other levels of government. Finland includes bridge cleaning as a standard maintenance item, as do other Scandinavian countries. Finland has published the SILKO bridge repair manual. Finland has also designated a set of reference bridges for research to monitor bridge performance. Norway demonstrated nicely prepared inspection manuals. In Norway, bridge inspectors must recommend the year to take remedial actions for bridge repairs. The Swedish bridge management system SAFEBRO and the new program BaTMan include a knowledge database containing data on unit prices, technical solutions, methods of measurement, and models for changes in condition for the assessment of the damage. In the United Kingdom, bridge waterproofing systems were an important element of bridge preservation and repair. This also appeared common in other European and Scandinavian countries. The Transport Research Lab has published an application guide AG-43, *Repair of concrete in highway bridges: a practical guide* (http://www.trl.co.uk/abstracts/ag43summary.pdf).
Significance to Bridge/Structure Preservation and Maintenance	The National Bridge Inspection Standards, defined in Federal regulations, require owners of public bridges to inspect their bridges at least every 2 years. Materials to more easily identify and recommend preservation strategies during inspections would make the inspection more beneficial and cost effective. This would also complement efforts to apply asset management concepts to the national bridge inventory as a means to more economically manage the Nation's bridge stock.

Suggested Actions	1. Follow up with contacts from this scan on the existence and availability of maintenance practice manuals or other references that might contribute to development of a best practices manual for bridge preservation and repair. 2. Compile and compare to similar U.S. literature. 3. Determine viability of preparing practical best practices guide(s) to aid in bridge preservation and repair. 4. Alternatively, assemble a practical guide to available references on bridge preservation and repair.
References	1. United Kingdom—Transport Research Laboratory, Application Guide AG-43, *Repair of concrete in highway bridges— a practical guide*, www.trl.co.uk/abstracts/ag43summary.pdf. 2. South Africa—CSIR (Council for Scientific and Industrial Research) Division of Roads and Transport Technology, www.csir.co.za. 3. Switzerland—Ecole polytechnique fédérale de Lausanne (EPFL), www.epfl.ch/Eplace.htm.
Comments	Excerpt of current policy of County Road Administration of Michigan (CRAM) on bridge preservation: *Due to the limited amount of bridge funds currently available for local agency bridge needs, timely and costly rehabilitation of local agency bridges is often passed over in favor of critically needed bridge replacement. In order to establish a balanced "asset management" approach to correcting local agency bridge deficiencies, CRAM supports establishing a bridge rehabilitation program/fund from a portion of any future increase in bridge funds dedicated to local agencies.*

Finding 5—Asset Evaluation Methods

Bridge Preservation and Maintenance in Europe and South Africa International Technology Scanning Program March 28 to April 13, 2003	
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, and United Kingdom	
Recommendation	Perform a synthesis of asset evaluation processes by foreign countries.
Brief Description	Several countries have begun quantifying the asset value of their bridge inventories. The methods presented differ from the concepts being employed in the United States. NCHRP Project 19-4 is studying the different practices being used in the United States to comply with the Government Accounting Standards Board Statement 34 (GASB-34).
Reference Countries	France, Germany, Finland, South Africa, Sweden, and Denmark
Elaboration and Figures	Each country had a method to determine the value of their bridge inventory. Most included as a minimum the expected current replacement cost. Sweden used a method called lack of capital value that took into consideration the existing condition of the structure. Other countries, like the United Kingdom, also had a process to calculate a reduced value due to the current condition that appeared to be based on load capacity.
Significance to Bridge/Structure Preservation and Maintenance	GASB-34 requires all public agencies to evaluate the asset value of their infrastructure items. NCHRP Project 19-4 performed a study of the practices in the United States and found a variety of methods used to determine the asset value of bridges. In the countries visited in the scanning study, a variety of methods are used to determine the value of the bridge inventory and to determine the current value due to deterioration. The methods employed by these countries may prove helpful in developing a standardized method of asset valuation. A more detailed study or synthesis of each country's practice is needed, as well as a study of countries not visited in this study. The information gathered under this synthesis may have significant influence on the direction of U.S. practices.
Suggested Actions	Sponsor a synthesis to study the methods used to determine how foreign countries value their bridge assets.
Comments	Sweden had a particularly interesting method to determine a bridge's value based on a lack of capital value. This appeared to have a direction relationship to the amount of work needed to repair a bridge or restore a required level of service.

Finding 6—Inspection Frequency

Bridge Preservation and Maintenance in Europe and South Africa **International Technology Scanning Program** **March 28 to April 13, 2003**		
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom		
Recommendation	Initiate a study to develop a rational approach for determining frequencies of various types of bridge inspections.	
Brief Description	Most countries base bridge inspection frequency on specific factors, such as type of structure, condition, age, etc., rather than an arbitrary time interval.	
Reference Countries	France, Germany, Finland, South Africa, Norway, Sweden, United Kingdom, and Denmark	
Elaboration and Figures	In South Africa, bridge inspection frequency varies from 3 to 5 years, depending on the type of inspection and/or severity of distress. Four levels of inspection are defined: visual (every 5 years), principal (similar to U.S. biennial inspections), monitoring (more indepth, as needed), and verification (random sample each year). In France, frequency and depth of inspection vary with condition and robustness of structures, typically ranging from 3 to 9 years. Three-year inspections are generally cursory. More in-depth inspections are performed every 9 years. Germany has defined four levels of inspection: superficial (performed by maintenance personnel on a quarterly basis, require no special bridge knowledge, and are primarily visual), general (performed every 3 years), major (similar to U.S. biennial inspections, performed every 6 years), and special (as needed to assess damage). In Denmark, three types of inspections are defined. The principal inspection, similar to the U.S. biennial inspection, is performed every 1 to 6 years. Special inspections are carried out as necessary when damage has occurred or is suspected. Routine inspections are performed daily to every 6 months.	

	In Sweden, five inspection types are defined with varying frequencies. Regular inspections are cursory in nature and are typically performed by maintenance contractors. Superficial inspections, also cursory, are performed twice a year for bridges on the national network and once a year for all other bridges. Major inspections, similar to U.S. biennial inspections, are performed every 6 years. General inspections are performed between major inspections to monitor defects noted during the last major inspection. Special inspections, typically involving NDT, are performed every 3 years as necessary to assess specific damage. Bridge inspection intervals in Finland are based on the inspector's recommendation and commonly range from 4 to 8 years, depending on bridge condition. In Norway, five inspection types are identified: acceptance (after construction), warranty (after 3 years), general (to look for severe problems on an annual or biennial basis), major (local bridge engineer determines frequency using expert judgment), and special (as needed). In the United Kingdom, general inspections are performed every 2 years, typically involving a cursory review for major safety defects. Principal inspections, similar to the U.S. biennial inspection, are performed every 6 years.	
Significance to Bridge/Structure Preservation and Maintenance (Start with a brief summary of U.S. practice, if necessary)	Title 23, Section 151, of the U.S. Code requires the Secretary of Transportation to define minimum requirements for bridge inspection standards, including a maximum time period between inspections. The National Bridge Inspection Standards, defined in Federal regulations, require state DOTs to inspect their bridges at least every 2 years. FHWA has granted case-by-case approval of an extended frequency, not exceeding 4 years, to a few States.	
Suggested Actions (Implementation or Implementation Plan)		
References	Notes from presentations and discussions.	
For additional information, see:		
Comments	U.K. officials are investigating use of a risk-based approach to determine frequency so that resources could be targeted to structures with the greatest need.	

Finding 7—Inspector Qualification

Bridge Preservation and Maintenance in Europe and South Africa International Technology Scanning Program March 28 to April 13, 2003	
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom	
Recommendation	Develop the framework for a process of qualifying bridge inspectors based on tiered and targeted levels of training along with periodic recertification and recalibration. Investigate the costs and benefits of implementing at the national level.
Brief Description	Several countries have implemented programs that qualify inspectors based on the training received for various structure types. A few programs also incorporate periodic calibration and certification processes.
Reference Countries	France, Germany, Finland, South Africa, Sweden, and Denmark
Elaboration and Figures	Bridge inspectors in South Africa are professional engineers with at least 5 years of design experience (4 years if inspecting culverts). Although no minimum training requirements have been set, inspection courses are offered. In Germany, inspectors must have a civil engineering education and 5 years of bridge inspection experience, complete a 1-week training course, and meet physical condition requirements. In France, three levels of inspection staff have been defined: project manager (engineer), inspector, and inspection agent. Minimum requirements related to education, level of experience, and successful completion of training modules have been established. A formal certification process has been implemented involving a written test and field demonstration of skills. Denmark relies on a mentoring approach to insure that inspectors develop appropriate skills. New inspectors must work with experienced staff for an undefined period of time. In Sweden, bridge inspectors must have an engineering background, knowledge, and experience in addition to specific training. The training involves 3 days of class work, 2 days of field application, and a final test. In Finland, inspectors must complete an initial training program involving 4 days of class work and 2 days of fieldwork, and an examination. Yearly training, involving field inspection and a calibration of results, is also required. Repeated weak results during training can lead to loss of certification.
Significance to Bridge/Structure Preservation and Maintenance (Start with a brief summary of U.S. practice, if necessary)	Title 23, Section 151, of the U.S. Code requires the Secretary of Transportation to define minimum requirements for bridge inspection standards, including establishment of qualifications for those charged with carrying out the inspections. The National Bridge Inspection Standards, defined in Federal regulations, outline minimum qualifications for individuals in charge of inspection programs and team leaders. The qualifications do not currently consider varying levels of training based on the types of inspections being performed, nor do they require testing, formal certification, or calibration.
Suggested Actions (Implementation or Implementation Plan)	
References	Notes from presentations and discussions.
For additional informa-	

tion, see:	
Comments	The French and Germans, in particular, have recognized that bridge management systems rely primarily on data collected during bridge inspections, so the use of skilled and well-trained inspectors is vitally important.

Finding 8—Concrete Waterproofing

Bridge Preservation and Maintenance in Europe and South Africa **International Technology Scanning Program** **March 28 to April 13, 2003**	
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom	
Recommendation	Perform a study of deck waterproofing systems used in Europe and the United States and their effectiveness compared to other deck corrosion systems (epoxy rebar, etc.).
Brief Description	Most other countries have a strong reliance on the waterproofing of bridge decks to retard and prevent deterioration. U.S. practices rely more on epoxy-coated steel to retard or prevent deck deterioration. A formal study of these practices should be made to evaluate the effectiveness of the different methods and their life cycle costs. This finding is virtually the same as a finding in a 1995 scan and is documented in NCHRP report 381.
Reference Countries	France, Germany, Finland, South Africa, Sweden, and Denmark
Elaboration and Figures	A common deck protection feature employed by the countries visited was a waterproofing system. Typically to protect a deck, a waterproof membrane is installed on top of a concrete deck. This membrane is protected with a concrete wearing surface (asphalt, portland cement, latex, etc.). U.S. practices rely more on epoxy-coated steels and other construction details (more rebar coverage, polymer concretes, etc.).
Significance to Bridge/Structure Preservation and Maintenance (Start with a brief summary of U.S. practice, if necessary)	Bridge deck deterioration is one of the most costly aspects of maintaining an inventory of bridges. Any efforts to minimize the repairs needed on decks have a significant impact on the amount of money needed to maintain the bridge inventory. Waterproofing systems and corrosion-resistant details (epoxy-coated steels, etc.) help protect the deck from deterioration but add costs to the initial construction or ongoing maintenance of the deck. These factors influence the long-term life cycle costs of the bridge and should be reviewed to determine the most cost-effective strategy. It was somewhat surprising that the countries visited still rely heavily on waterproofing systems, while the trend in the United States is departing from this philosophy. Why? Is the U.S. experience with waterproofing systems bad compared to the European experiences? This needs further study. The desire to further study this issue was also raised in the previous scan and documented in NCHRP report 381.
Suggested Actions (Implementation or Implementation Plan)	Pursue a research study on the effectiveness of protecting concrete decks from deterioration. This study would include the use of waterproofing systems and the installation of corrosion-resistant features.
References	Notes from presentations and discussions. NCHRP Report #381, *Report on 1995 Scanning Review of European Structures*
For additional information, see:	NCHRP Report #381, *Report on 1995 Scanning Review of European Structures*
Comments	

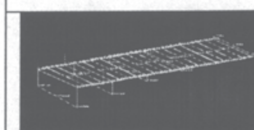
Bridge Preservation and Maintenance in Europe and South Africa International Technology Scanning Program March 28 to April 13, 2003	
	South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom
Recommendation	Promote best practice maintenance approaches, such as bridge washing, in coordination with inspections.
Brief Description	Several countries have demonstrated the benefits of proactive, scheduled preventive maintenance programs on minimizing bridge preservation costs. Typical activities include washing, sweeping, removing debris, and applying sealers. Some have implemented such programs and others have made efforts to justify implementation of programs based on bridge management life cycle cost methods.
Reference Countries	Germany, Switzerland, Norway, and Denmark
Elaboration and Figures	In Europe and South Africa, where bridges are predominately constructed of prestressed or reinforced concrete, owner agencies have recognized the benefit of scheduled cleaning and preventive maintenance to avoid corrective repairs and rehabilitation work. Use of coated reinforcement is not common in Europe, so proactive methods to prevent moisture and chloride intrusion take on added importance. Common activities include washing, sweeping, applying sealants, repairing joints, and using protective membranes. Switzerland is implementing a strategic "no surprises" maintenance approach that includes planned and scheduled routine maintenance. The goal is to minimize traffic disruption by reducing major maintenance cycles to 10-year intervals. Analysis by most reference countries shows a need for maintenance programs to be funded annually at 1.0-1.2 percent of the bridge network's replacement value, and most are actively taking measures to justify funding to attain these goals. Large numbers of the former East German bridges, which were not well maintained before unification, have needed replacement (at a cost of DM56 m^2). In West Germany, which had sustained maintenance programs during the same period, fewer bridges have needed replacement and preservation costs have been significantly lower. France and Denmark document standard maintenance practices, with Denmark incorporating unit prices and instructions in its bridge management system to assist in preparing bid documents. Norway outsources its bridge-washing program, which is common practice for most routine maintenance work in Europe and South Africa. Norway also times its washing just before scheduled bridge inspections, which provides for better visual assessments.
Significance to Bridge/Structure Preservation and Maintenance (Start with a brief summary of U.S. practice, if necessary)	In the United States, the benefits of scheduled routine scheduled maintenance is generally recognized and many state DOTs have programs in effect. FHWA is allowing more flexibility in using Federal bridge funds on maintenance activities on Interstate and National Highway System bridges. While the benefits are intuitive, demonstrating benefit/costs statistically is difficult, and justifying funding for such programs to administrators can be a barrier to full implementation. The nature of routine maintenance also makes it a target for fiscal cuts in times of budget shortfalls.

Suggested Actions (Implementation or Implementation Plan)	1. Evaluate the effectiveness of routine maintenance activities to develop and publicize best practices. 2. Encourage and promote the implementation of bridge management analysis techniques or BMS modules (such as Pontis) that can analyze the benefit/cost of routine preventive maintenance. 3. Encourage the scheduling of bridge washing just before scheduled bridge inspections.
References	
For additional information, see:	
Comments	

Finding 10—Integrity Monitoring

Bridge Preservation and Maintenance in Europe and South Africa **International Technology Scanning Program** **March 28 to April 13, 2003**	
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom	
Recommendation	Assess and promote the use of simple bridge integrity monitoring/warning systems for extreme events; e.g., vessel collision.
Brief Description	Several countries have warning systems to indicate that a bridge or major structure is experiencing distress because of an extreme event, such as flood scour, earthquake, or ship impact. These systems are directed toward structural integrity and should close the structure to traffic, if needed. These systems are quite simple and are typically associated with a break in some type of closed-loop system, such as a circuit or fiber optic line.
Reference Countries	France, Sweden, and Denmark
Elaboration and Figures	Such systems could be simply employed in the United States, particularly for major crossings. With increasing concern about terrorist activities and the structural integrity of bridges, such systems are of increased importance. Traffic closure methods could follow typical processes such as lights, gates, etc.
Significance to Bridge/Structure Preservation and Maintenance	These simple systems could be easily installed for major spans in the United States. The impact would be life saving. Both nature- and man-caused hazards could be addressed in the same system.
Suggested Actions	
References	

Finding 11—Load Testing and Rating

Bridge Preservation and Maintenance in Europe and South Africa **International Technology Scanning Program** **March 28 to April 13, 2003**		
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom		
Recommendation	Review current U.S. practice for use of standardized load testing/rating of trucks and systems.	
Brief Description	In most countries visited, it is standard practice to use finite element model (FEM) or grillage methods to distribute the truck loading to the bridge superstructure when performing bridge load rating. In the United States, the AASHTO simplified distribution factor (S/5.5) appears to remain common practice (or LRFD distribution factors).	
Reference Countries	South Africa, Germany, France, Switzerland, Denmark, Norway, Finland, and Sweden	
Elaboration and Figures	The standard practice in most countries appears to be a refined analysis, typically finite element or grillage models. Design engineers are educated to a level required to understand these methods and their application. In U.S. practice, this is often not the case. Additionally, funding methods for design are different in countries and often encourage effective analysis and possible economy. Models are often available for operations, such as posting or heavy loads. The U.S. practice for design is heading in the opposite direction (i.e., simplification). As extra materials for new design are relatively inexpensive, and DOTs have difficulty hiring engineers with this level of expertise, the simplification strategy appears appropriate. For evaluation, however, such methods make sense and can significantly affect the posting or heavy load operation. Much can be learned about the more rigorous approach and its application here. The issues are not technology, but rather office practice, available software, and appropriate training.	
Significance to Bridge/Structure Preservation and Maintenance	More refined analysis could have a significant impact on bridge evaluation and associated operations. The primary issue is not technical, but rather implementation and training.	
Suggested Actions	1. Review current state of practice for bridge load rating and distributing the live load to the superstructure. 2. Determine why there is resistance to using more refined methods of analysis. 3. Promote the use of more refined methods of analysis with NHI/FHWA short courses on refined analysis.	

Finding 12—Risk-Based Management

Bridge Preservation and Maintenance in Europe and South Africa **International Technology Scanning Program** **March 28 to April 13, 2003**	
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom	
Recommendation	Support an NCHRP project to pursue the development of a risk-based management process that includes the consideration of serviceability issues.
Brief Description	Several countries indicated their desire to move to a completely integrated asset management system. Each country indicated that the inclusion of risk was a necessary component. The United Kingdom appeared to have a head start in determining risk and quantifying risk parameters that could form the basis of a decision process to compare different bridge vulnerabilities with other vulnerabilities. It had warning systems to indicate that a bridge or major structure was experiencing distress because of an extreme event, such as flood scour, earthquake, or ship impact. These systems are directed toward structural integrity should close the structure to traffic. These systems are simple and typically are associated with a break in some type of closed-loop system, such as a circuit or fiber optic line.
Reference Countries	Northern Europe and United Kingdom
Elaboration and Figures	Some risks are clearly greater than are others.
Significance to Bridge/Structure Preservation and Maintenance	Most decisions have some risk assessment process involved. The decision to repair one bridge versus another is affected by the risk assumed if repairs are not made. Many State DOTs have programs targeted at reducing risk. Scour mitigation, seismic retrofit, or protection against collisions could be addressed with risk-based programs. These programs typically assess a particular bridge's vulnerability to an event like floods, earthquakes, collisions, or exposure. The risk assessment procedures do not quantify the risk, but instead rank bridges against each other. To better compare a particular vulnerability of one bridge to a different vulnerability of another bridge, it is necessary to quantify the particular risks for each. If the risks could be objectively quantified, many decisions now based on engineering judgment could be better supported. Risk-based decisions could also facilitate the integration of other asset management systems such as pavement and congestion relief, support complete life cycle analysis information, and allow for a more defined benefit/cost analysis.
	Initiate research projects to develop objective procedures to quantify risks associated with various bridge vulnerabilities including, but not limited to, deterioration, heavy traffic loads, earthquakes, floods, collisions, and terrorism.

Finding 13—Manual/Documents Synthesis

Bridge Preservation and Maintenance in Europe and South Africa **International Technology Scanning Program** **March 28 to April 13, 2003**		
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom		
Recommendation	Compare manuals for bridge condition reporting and maintenance used in other countries with U.S. manuals and develop a synthesis.	
Brief Description	Several countries have comprehensive bridge inspection and bridge maintenance manuals. They may contain many ideas that could be incorporated into U.S. manuals, as well as various bridge maintenance techniques not practiced or documented in the United States.	
Reference Countries	South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, and United Kingdom	
Elaboration and Figures	Most countries have well-written and illustrated inspection manual that exceed the manuals used in the United States in quality of presentation and content.	
Significance to Bridge/Structure Preservation and Maintenance (Start with a brief summary of U.S. practice, if necessary)		
Suggested Actions (Implementation or Implementation Plan)	1. Solicit copies of bridge inspection and bridge maintenance manuals from various countries. 2. Assemble a team(s) to review these manuals and assemble the best ideas, presentations, and topics from them. 3. Make necessary recommendations to appropriate agencies and associations based on the findings.	
References		

Finding 14—WIM Screening for Overloads

Bridge Preservation and Maintenance in Europe and South Africa **International Technology Scanning Program** **March 28 to April 13, 2003**	
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom	
Recommendation	Promote the use of bridge weigh-in-motion (WIM) as a screening tool for overload enforcement.
Brief Description	Weigh-in-motion has been a proven technology to monitor the distribution of vehicle loads on a highway and can be effective in detecting overload vehicles. WIM results are not accepted as legal proof of an overload, so WIM has not been used for enforcement purposes. In South Africa, WIM is being used as a screening mechanism in the overload enforcement process on major corridor routes.
Reference Countries	South Africa
Elaboration and Figures	Regulation and enforcement of overloads has historically been a problem in South Africa because of the presence of industries that produce large loads (e.g., mining), the developing nature of large parts South Africa and neighboring countries, and the inadequate resources available for enforcement. In recent years, the South African National Road Agency has expanded is national road network using concession contracts in which the concessionaire designs, builds, and operates major corridor toll highways. On some of these toll highways, bridge WIM installations have been positioned before fixed vehicle weigh stations. The WIM installation is used to detect a potential overload vehicle and, if detected, it activates a signal that directs the vehicle to exit into the weigh station. The vehicle is then weighed and permits are checked for compliance. The weigh stations are set up with a traffic court to prosecute overload violators on the spot. The court has the power to issue fines and/or impound illegal vehicles. Actual enforcement operations are under the jurisdiction of the South African provincial governments. Since the installation of this enforcement system on the toll highways, illegal overloads have decreased from 16 to 10 percent, and 80 percent of vehicles weighed are within the 5 percent allowable tolerance.
Significance to Bridge/Structure Preservation and Maintenance (Start with a brief summary of U.S. practice, if necessary)	WIM technology is a proven method to measure the magnitude and frequency distribution of vehicular loads, including overloads. Enforcement codes do not recognize WIM as a means to determine the weight of an individual truck for legal compliance. WIM systems could be configured to detect the likely passage of an illegal overload or overload permit vehicle, and serve as a screening method to selectively weigh vehicles with conventional scales for enforcement. WIM screening would reduce the number of trucks that have to be weighed with scales, improving the efficiency of the weight-enforcement process and reducing inconvenience to most legal trucks. Improvement of enforcement could result in fewer illegal overloads, which would help reduce bridge damage and deterioration.
Suggested Actions (Implementation or Implementation Plan)	Investigate the use of bridge WIM technologies for use in overload enforcement as a screening mechanism in conjunction with weigh stations or other weight enforcement operations.
References	

For additional information, see:	
Comments	

Finding 15—NDT for Concrete Permeability

<table>
<tr><th colspan="2">Bridge Preservation and Maintenance in Europe and South Africa
International Technology Scanning Program
March 28 to April 13, 2003</th></tr>
<tr><td colspan="2">South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom</td></tr>
<tr><td>Recommendation</td><td>Investigate nondestructive test methods to determine in situ concrete permeability.</td></tr>
<tr><td>Brief Description</td><td>Determine the permeability of in situ concrete through nondestructive testing. Lower permeability results in better concrete performance.</td></tr>
<tr><td>Reference Countries</td><td>Switzerland and Finland</td></tr>
<tr><td>Elaboration and Figures</td><td></td></tr>
<tr><td colspan="2">The Swiss are researching a methodology to determine the permeability of in situ concrete through nondestructive testing. In this method, a vacuum is placed on a concrete surface and air is pulled through the concrete pores. Although the size of air molecules is one-tenth that of water molecules, a ratio can determine the permeability of the concrete compared to other permeability measurements. This could become a valuable field test to quantify or determine permeability required by specification. The concrete permeability to liquids would not be the final goal, rather the resistance to penetration of aggressive ions through the concrete. The durability of bridge decks relies as much on their resistance to cracking as it does on their resistance to chloride penetration in uncracked regions. The Swiss permeability test may prove to be a more convenient method for evaluating low permeability in the field, but care needs to taken to make sure that it does not result in unintended consequences, such as high cement contents that can cause cracking.

The number of variables could create a range too large to be useful, except on a specific mix design. Some of these variables are as follows:
• Concrete cementitious materials—portland cement (type), silica fume, ground granulated blast furnace (GGBF) slag (Gr), fly ash (type)
• Blaine fineness of cementitious materials
• Concrete air content
• Concrete admixtures—water reducers, set retarders, plasticizers, self-consolidating concrete (SCC) admixtures
• Concrete surface sealers—water-based sealers (monkey blood), wax-based sealers (white pigment), linseed oil emulsion
• Curing and drying time—wet cure, surface dry time
• Concrete strength limits—f'_c at 7 days, 14 days, 21 days, 28 days, 56 days.
• Surface preparation—water blast, sand blast

Comparisons to other standard methods will need to be determined. The following are recommended:
• AASHTO T 259 Resistance of Concrete to Chloride Penetration, which involves ponding with a 3 percent NaCl solution for 90 days.
• A proposed AASHTO test method is the Standard Test Method for Predicting Chloride Penetration of Hydraulic Cement Concrete by the Rapid Migration Procedure. This test can be run much like AASHTO 277 (ASTM C 1202), Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration, but instead of measuring coulombs, it measures the chloride ion content that has actually penetrated the specimen.</td></tr>
<tr><td>Significance to Bridge/Structure Preservation and Maintenance</td><td>Lower permeability increases concrete serviceability performance. This is particularly applicable to bridge decks and concrete roadways. A reliable and simple NDT procedure to test in situ concrete could result in many significant advancements, including research of current and future concrete construction methods and mixes, performance-based acceptance procedures, etc.</td></tr>
<tr><td>Suggested Actions</td><td>Synthesis study that could result in a research project or implementation of existing results.</td></tr>
<tr><td>References</td><td>Standard Test Method for Predicting Chloride Penetration of Hydraulic Cement Concrete by the Rapid Migration Procedure</td></tr>
</table>

Finding 16—Obtain and Assess Technologies

Bridge Preservation and Maintenance in Europe and South Africa International Technology Scanning Program March 28 to April 13, 2003	
South Africa, Switzerland, Germany, France, Denmark, Norway, Finland, Sweden, United Kingdom	
Recommendation	Obtain and synthesize the best practices for methods and manuals for repairing damaged bridges.
Brief Description	Several countries have robust repair manuals that contain explicit graphics and illustrations.
Reference Countries	Finland, Sweden, Germany, and France
Elaboration and Figures	These countries put significant time and effort into their publications, including attention to graphics, illustrations, paper quality, and open formats. The countries have bridge repair manuals that should be reviewed and synthesized. It appears that some of the content, as well as the format, could be applicable for use in a U.S. manual.
Significance to Bridge/Structure Preservation and Maintenance	Better guidelines for proper repair of bridges that could result in better application and economy.
Suggested Actions	Implement a synthesis study to review all manuals, build a framework for a U.S. manual, and then use the manuals in addition to U.S. practice to complete the framework.

Finding No.	Topic	Description	Type	AKA	Importance Level	Source Country(s)
1	BMS	Bridge management systems have been effective in the political arena in most countries.	Confirmation	start		Scandinavia
2	Inspection	Denmark's mentoring program appears exceptionally strong and effective.	Innovation		Medium	Denmark
3	Inspection	Inspection frequency is based on a rational set of criteria. U.S. inspection frequency approach should be reconsidered.	Innovation		High	Scandinavia
4	Inspection	Inspector annual certification appears to be well done in Finland.	Innovation	10	Same as 10	Finland
5	BMS	Bridge reference group is studying deterioration modeling.	Follow-up		Medium	Finland
6	BMS	All countries have a structures management system (not just BMS).	Information	28, 86		Most of Scandinavia
7	Repair	SILKO is Finland's bridge repair manual (short repair manual).	Documentation	9, 35	High	Finland
8	BMS	Manuals tied bridge distress to recommendations.	Follow-up		Medium	Norway and Sweden
9	Repair	Knowledge database for typical repairs is a good idea.				Sweden
10	Inspection	Finland—deviation in defect score, QA/QC, tests, recertification, inspection of two test bridges. There may be a lot there. It affects future contracts.	Innovation		High	Finland
11	BMS	Denmark has a good definition of maintenance and repair.	Information	31		Denmark
12	Miscellaneous	Washing structures is common for steel structures. Timing is just before inspection.	Application		Medium	Norway and Finland— entire bridge; Sweden— deck, joints, barrier area, debris; Denmark—joints and debris
13	Operations	Load rating with a spectrum to address operations.	Information			Finland
14	BMS	Denmark's special structures management system, BMMS, looks robust. Operating manuals are developed for the special structures.	Follow-up	22	High	Denmark

Finding No.	Topic	Description	Type	AKA	Importance Level	Source Country(s)
15	Inspection	Clarify Sweden's and Denmark's certification of underwater inspectors.	Question		Medium	Sweden and Denmark
16	BMS	Denmark looked at additional costs of construction and user costs associated with delaying action.	Follow-up	82, 47	Low	Denmark
17	Operations	Warning devices for bridge failures are used for ship impact and high wind.	Application		Medium	Sweden and Denmark
18	BMS	DANBro generates detailed work order management system.	Information			Denmark
19	BMS	Risk-based maintenance is just starting. The consequences of not performing maintenance are considered.	Follow-up	84	High	Northern Europe
20	Inspection	Are routine inspections documented?	Question		Medium	Scandinavia
21	Inspection	Inspectors are well trained and qualified. They are given responsibility for recommendations on repair, inspection frequency, etc.	Innovation		High	Finland
22	BMS	They have add-on to basic management systems for special structures.				Northern Europe
23	BMS	Sweden's method of determining bridge asset value appears promising—"lack of capitol value."	Follow-up	27, 45, 87	Medium	Sweden
24	Inspection	NDT practices confirm those in the United States.	Confirmation		Low	Scandinavia
25	BMS	Is Finland's philosophy corridor management? How does it integrate pavement and bridge needs? How is optimization accomplished in a combined system (HiBris)?	Question		High	Finland
27	BMS	How is inventory valued, related to maintenance?				Scandinavia
28	BMS	France and Germany include all structures in inventory (culvert, walls, signs, signal structures).				France and Germany
29	Inspection	France uses a modularized approach to inspector qualifications related to structure types.	Innovation		High	France

Finding No.	Topic	Description	Type	AKA	Importance Level	Source Country(s)
30	General	Germany designs for constructibility, maintainability, and inspectability.	Application and Documentation		High	Germany
31	General	Germany has good definitions of different maintenance activities.	Information		Medium	Germany
32	Inspection	Germany uses a concrete durability testing performance specification matrix.	Innovation		Medium	Germany
33	Deterioration Modeling	France has a predictive model for corrosion/carbonation under development.	Information			France
34	BMS	Is the Swiss UPlaNS approach corridor based?	Question	46	High	Switzerland
35	Repair	France has a menu of concrete repairs (manual available).				France
36	Administration	France is moving to a decentralized system.	Information		Information	France
37	Administration	Germany has a centralized system.	Information			Germany
38	Inspection	France has physical tests, cross bow, and chart for good- and poor-quality concrete.	Innovation		Medium	France
39	BMS	The Swiss "no surprises" maintenance approach is to plan and schedule maintenance (i.e., be proactive).	Follow-up		Medium	Switzerland
40	Operations	Germany has guide for ultimate resistance for existing structures.	Documentation		Medium	Germany
41	Deterioration Modeling	Germany has future plans to consider service life models. Software is in development.	Information			Germany
42	BMS	Germany has two BMS—light/fast and regular.	Information			Germany
43	Operations	Germany uses simple and refined structural analysis.	Information			Germany
44	Miscellaneous	In Germany, lack of maintenance in the east is related to replacement of many bridges.	Information			Germany
45	BMS	European countries relate maintenance to value of assets. How is asset value determined?				All of Europe

Finding No.	Topic	Description	Type	AKA	Importance Level	Source Country(s)
46	BMS	The Swiss appear to be ahead in assessment management.				Switzerland
47	BMS	France and Germany both use the user-cost approach extensively.				France and Germany
48	Miscellaneous	The Swiss use high-performance concrete in overlays and cantilevers.	Research and development		Medium	Switzerland
49	Miscellaneous	All use methods for allocation of funding sources to maintenance of various assets.	Informational			All of Europe
51	Miscellaneous			5		Most of Europe
52	Operations	Germany—BELFA load testing truck.	Application		Low	Germany
53	Inspection	German inspector requirements are related to the physical condition of inspectors.	Innovation		High	Germany
54	Miscellaneous	German—DN 1076 (action?)	Documentation		High	Germany
55	Miscellaneous	Germany—different design and actual clearance standards.	Information	5		Germany
56	Inspection	None use chain drag. Check whether Germany uses radar.	Question		Medium	Germany
58	BMS	Defect-based management (DER).	Information			South Africa
59	Operations	On special loads and clearances, industry pays for retrofits.				South Africa
60	Operations	WIM is used for load screening, followed by enforcement at weigh stations.	Application		High	South Africa
61	Administration	Use of design-build-operate is widespread.	Information			South Africa
62	Inspection	Inspection data are logged on the Internet, although a signed paper is still required.	Information		Medium	South Africa
63	Inspection	Performance-based tests for concrete.	Innovation		Medium	South Africa
64	Operations	Very little, if any, load rating is performed. Note heavier design loads.	Information	65		South Africa
65	Operations	Very little, if any, load posting is done. Note heavier design loads.				South Africa
66	Miscellaneous	Design and analysis are based on grillage and/or three-dimensional analysis.	Information			South Africa

Finding No.	Topic	Description	Type	AKA	Importance Level	Source Country(s)
67	Inspection	Review visual assessment manual and compare with U.S. core elements.	Information		Medium	South Africa
68	Miscellaneous	A unique cable bridge construction method was used in that the bridge was constructed parallel to the road and then swung into place.	Information			South Africa
69	Inspection	Tiered level of inspection	Innovation		High	South Africa
70	Miscellaneous	I_c formula		91		South Africa
71	Miscellaneous	BCI formula	Information	91		South Africa
72	Inspection	Inspection intervals vary.	Innovation		High	South Africa
74	BMS	Photos and sketches are stored in BMS.	Information			South Africa
75	Inspection	Inspectors are professional engineers and have 5 years' experience and design experience.	Innovation		High	South Africa
76	BMS	BMS data are linked to GIS.	Information			South Africa
77	Inspection	Contractor fills out bridge inspection report on new bridges.	Information		Low	South Africa
78	Miscellaneous	Nearly all bridges are concrete. A few are steel or timber.	Information			South Africa
81	Operations	BD 86—abnormal load assessment.	Documentation		Medium	United Kingdom
81a	Operations	AILs (abnormal indivisible loads system/software) formalizes procedure for movement of abnormal loads.	Information			
82	BMS	BAPS bids and prioritization system (not implemented) defines the consequences of not funding a bid item. User costs and changes in whole-life cost are included.				United Kingdom
83	General	Pending EU change drove assessment strategies. The legal limit of 20 t increased to 38 t in the 1960s, and EU required 40 t. Many bridges did not meet the 38 t standard.	Information			United Kingdom
84	BMS	Developing a risk management system with a risk-scoring system.				United Kingdom

Finding No.	Topic	Description	Type	AKA	Importance Level	Source Country(s)
85	Inspection	Proposed knowledge-based asset integrity system for determining inspection frequency.	Innovation		High	United Kingdom
86	BMS	Structures management system (not just BMS) for walls, tunnels, etc.				United Kingdom
87	BMS	Residual life is based on load-carrying capacity. All asset values are based on residual life. Linear depreciation model is used.	Information			United Kingdom
88	BMS	BRIME provides a framework. Pieces have been adopted by various EC countries. Level 0 was created and implemented in several countries (i.e., do nothing).	Information			United Kingdom
89	Operations	BA 79 is a full reliability-based assessment that establishes five levels of load assessment.	Documentation		Medium	United Kingdom
90	General	Strong focus on bridge strength rather than bridge general health.				United Kingdom
90a		Many structures were designed for much lower loads than the previous U.K. standards and new EU 40 t standards.	Information			
91	BMS	Framework performance indicators are well defined.	Follow-up	70, 71	Medium	United Kingdom
92	Miscellaneous	United Kingdom is pleased with waterproofed decks and silane. Epoxy bars are not used.	Application		Medium	United Kingdom
93	Inspection	P/T corrosion issues have been addressed many ways, generally without success.	Confirmation		Low	United Kingdom
94	Administration	eGIF government intercommunication standards based on XML is required for all new efforts.	Follow-up		High	United Kingdom
95	Inspection	General inspection is done at 2-year intervals (formalized, binocular-distance inspection) and principle inspection is done every 6 years (arms' length).	Innovation	end	High	United Kingdom

Chapter Four
RECOMMENDATIONS

READY FOR IMPLEMENTATION

The scan team believes the following topics have potential for adoption into U.S. practice:

- **Management of roads structures.** Most scan countries use automated programs for maintenance management of retaining walls, sign structures, and most other roads structures in addition to bridges. Procedures for element-level modeling and condition reporting that are familiar for bridges can be readily extended to include other structures.

- **Management of special structures.** Some bridges have electrical, mechanical, data, or control systems necessary to traffic operations. These include movable bridges with hydraulics, signals, and gates, and major bridges with weather sensors, traffic monitors, signals, gates, toll plazas, maintenance buildings, and maintenance equipment. Maintenance management systems can be expanded with databases and software modules to manage the facilities and equipment for special structures.

SYNTHESES

For the following topics, the scan team recommends syntheses be prepared to inform U.S. engineers of the practices in the countries the team studied:

- **Performance indicators.** Numerical values for the health of bridges and networks include South Africa's bridge condition index, Sweden's lack of capital value method, United Kingdom's suite of indicators for condition, and Finland's repair index and rehabilitation index. A synthesis will report these performance indicators and note their use in maintenance programming.

- **Design for inspection.** Structural designs can simplify inspection by providing access to components and including devices that can be monitored during service. A synthesis will include the German methods of design review, and the Swedish use of permanent survey pegs.

- **Bridge repair methods and manuals.** A synthesis on publications by scan countries for bridge repair techniques and products will include publications listed in table 4. Translation of manuals into English is needed.

- **Inspection manuals.** Scan countries have excellent manuals guiding the work of bridge inspectors. A thorough review of these manuals in a synthesis is proposed. Translation of manuals into English is needed.

- **Asset valuation.** Each scan country has a method to determine the value of its bridge inventory. Most included the expected current replacement cost. Sweden employs a method called "lack of capital value" that considers the existing conditions of structures. Other countries, such as the United Kingdom, also calculate a reduced value because of the current condition and load capacity. A synthesis of these methods is proposed.

- **Housekeeping maintenance.** Scan countries have programs for routine annual actions to extend bridge service life. Deck washing, debris removal, and vegetation control are among these. A synthesis will review housekeeping actions and report on their effectiveness in extending bridge life.
- **Bridge integrity systems.** For bridges near seacoasts, scan countries employ warning systems that respond to high wind, ship collision with the structure, or other events that may warrant bridge closure. A synthesis on the deployment, operation, and reliability of these systems is proposed.
- **Load rating standardization.** All scan countries have activities in evaluation and routing of abnormal loads. A synthesis will review rating loads, note similarities among these loads, and review procedures for bridge analysis and the use of load tests to establish bridge capacity.

RESEARCH STUDIES

For the following topics, the scan team recommends that a study be conducted to make a complete report of foreign practice, relate foreign practice to U.S. practice, consider the impacts on U.S. practice, address outstanding technical issues, conduct tests, and validate methods as necessary to prepare them for use in the United States.

- **Bridge inspection.** Scan countries use certified inspectors to perform major inspections at 5- or 6-year intervals. Personnel with lesser training perform cursory inspections once or twice a year to assure that significant changes in bridges are discovered. A research study will examine reliable bridge inspection programs and identify the types, intervals, and training required of inspectors.
- **Deck waterproofing systems.** Scan countries report success with waterproofing to protect reinforced concrete members. A research study will review the performance of concrete decks with membranes plus asphalt, and concrete members on which sealers generally are used.
- **Zero maintenance.** Swiss FEDRO is studying a concept of zero maintenance. The concept combines improved durability in structures and coordination of all maintenance activities on a section of road to achieve long periods of unimpaired operation. A U.S. study of the concept will evaluate the costs or savings of this approach, and address technologies needed for such long-range planning.
- **Risk-based bridge management.** The United Kingdom includes uncertainty in deterioration models, and computes the costs for potential traffic delays not anticipated in the network plan for maintenance. Sweden, Norway, and Finland compute the sensitivity of maintenance costs to project delay. In general, the disruption of a maintenance plan because of unexpected failures increases costs and constitutes a risk in the network plan. A study of risk evaluation and the inclusion of risk in network optimization is proposed.

- **Weigh-in-motion.** Some scan countries (South Africa, Germany, France) are considering the use of weigh-in-motion (WIM) to monitor truck loads and enforce load limits. WIM may be used to select vehicles that must be directed to weigh stations for evaluation. Sweden and Switzerland use WIM to monitor axle loads. Sweden plans to establish a national control program for overloads. Switzerland employs data on axle loads to update design standards. A study of WIM use to identify overloads is proposed.
- **Concrete permeability.** Concrete permeability is proposed as a chief measure of concrete durability, since the movement of water and contaminants is an important cause of deterioration. A study of in-service measure of permeability (Torrent meter) and of the correlation of permeability and durability is proposed.

FOLLOW-UP

The scan team recommends that a small project be undertaken to collect additional information and report on the importance and potential benefits to U.S. practice of the Swiss FEDRO UPlaNS approach to coordinated management of all roads assets.

The scan team recommends that advances in nondestructive testing, and especially the development of standards, manuals, and guides for testing methods, be monitored on a continuing basis.

Appendix A
SCAN TEAM AND PARTICIPANTS

U.S. SCAN TEAM

Kenneth Hurst (co-chair)	Kansas Department of Transportation
George Romack (co-chair)	Federal Highway Administration
George Christian	New York State Department of Transportation
Thomas Everett	Federal Highway Administration
Ian Friedland	Federal Highway Administration
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Richard Shepard	California Department of Transportation
Todd Thompson	South Dakota Department of Transportation
Ronald Young	Alcona County, MI, Road Commission

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Dieter Silbernagl	South Africa	UWP Consulting
Susanne Troive	Sweden	Swedish National Road Administration
Walter Waldis	Switzerland	Baudepartement des Kantons Aargau
Peter Matt	Switzerland	Engineering Consultant
Bryan Adey	Switzerland	Swiss Federal Institute of Technology—Lausanne
Emmanuel Denarie	Switzerland	Swiss Federal Institute of Technology—Lausanne
Manfred Hirt	Switzerland	Swiss Federal Institute of Technology—Lausanne
Thomas Keller	Switzerland	Swiss Federal Institute of Technology—Lausanne
Jean-Pierre Joris	Switzerland	Swiss Federal Roads Office
Jena-Bernard Duchoud	Switzerland	Swiss Federal Roads Office
Johnny Rojas	Switzerland	Swiss Federal Roads Office
Michel Donzel	Switzerland	Swiss Federal Roads Office
Michel Egger	Switzerland	Swiss Federal Roads Office
Willi Schuler	Switzerland	Swiss Federal Roads Office
Andrew Cook	United Kingdom	Highways Agency
Brian Hill	United Kingdom	Highways Agency
Gerry Hayter	United Kingdom	Highways Agency
James Hardy	United Kingdom	Highways Agency
Mark Neave	United Kingdom	Highways Agency
Martin Potts	United Kingdom	Highways Agency
Victoria Hogg	United Kingdom	Highways Agency
Albert Daly	United Kingdom	Transport Research Lab

David Cullington	United Kingdom	Transport Research Lab
Peter Vassie	United Kingdom	Transport Research Lab
Richard Woodward	United Kingdom	Transport Research Lab
Thomas Collins	United Kingdom	Welsh Assembly Government Transport Directorate

SCAN TEAM BIOGRAPHIES

Kenneth F. Hurst, (AASHTO co-chair), is the engineering manager-state bridge officer for the Kansas Department of Transportation (KDOT) in Topeka, KS. He manages the Bridge Design Section, Bridge Management Section, and Special Assignments Unit. The Special Assignment Unit addresses computer programming and support, as well as management reports and support for the Bridge Office. He has been with KDOT since 1966 and has represented Kansas on the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Bridges and Structures since 1984. He chairs the Technical Committees for Construction and Computers. He is active in AASHTOWare software development and is the chair of the BRIDGEWare Task Force that includes Pontis (bridge management), Virtis (bridge load rating) and Opis (bridge design analysis and code checking). Hurst graduated from the University of Nebraska-Lincoln with a bachelor's degree in civil engineering. He is a registered professional engineer in Kansas and a member of the American Welding Society, Precast/Prestressed Concrete Institute, National Bridge Research Organization Advisory Panel, National Steel Bridge Alliance's Steel Bridge Collaboration Steering Committee, and the American Society of Civil Engineers. He is the K-Tran Area panel leader for structures for KDOT's research program.

George P. Romack, (FHWA co-chair) is a bridge engineer for the Federal Highway Administration (FHWA) in Washington, DC. Romack directs the Structures Management Program for FHWA's Office of Infrastructure. His duties include assisting the States in implementing the Pontis Bridge Management System, developing guidance for managing highway and transit tunnels, and providing expertise to the States in managing and maintaining highway bridges. Before joining FHWA's headquarters staff in 1977, he served as a structural design engineer for the Eastern Federal Lands Highway Division in Arlington, VA. Romack is a graduate of the Virginia Polytechnic and State University and is a licensed professional engineer in the District of Columbia. He is chair of the PIARC Committee C-11 Working Group, a member of the Transportation Research Board's Committee on Bridge Management, and a member of the American Society of Engineers' Committee on Bridge Management.

George Christian is a principal civil engineer for the New York State Department of Transportation (NYSDOT) in Albany, NY. Christian directs the department's Bridge Design Services Bureau, responsible for producing designs and contract plans for bridge projects with a cumulative construction value of $100 million a year. He also oversees the development of bridge design standards and policies and design automation for NYSDOT. Before assuming his present position in 1992, he directed the department's Bridge Programming and Evaluation Services Bureau, where he was responsible for implementing and operating bridge inspection, inventory, load rating, and bridge safety assurance programs. Christian is a graduate of Clarkson University and holds a master's degree in civil engineering from Rensselaer Polytechnic Institute. He is a licensed professional engineer in New York and serves on the AASHTO Bridge Committee, Evaluation and Rehabilitation Technical Committee, Bridge Technical Committee for Computers, and BRIDGEWare Joint Development Task Force.

Thomas Everett is the bridge programs team leader in the FHWA Office of Bridge Technology in Washington, DC. Everett manages Federal bridge programs, including the Highway Bridge Replacement and Rehabilitation Program and the National Bridge Inspection Standards. Before joining the Office of Bridge Technology, Everett served as a bridge engineer in Tennessee, and as a structural engineer in the former Regional Office for Structures in Baltimore, MD. Everett is a graduate of Rutgers University and holds a master's degree in civil engineering from Johns Hopkins University. He is a licensed professional engineer in Rhode Island and Tennessee.

Ian M. Friedland is bridge technology engineer for FHWA, where he provides national leadership and expert technical advice on the development and delivery of new technologies in bridge engineering to FHWA field offices and State transportation agencies. Before joining FHWA in 2002, Friedland was associate director for development with the Applied Technology Council. From 1992 through 1999, he was assistant director for transportation research at the Multidisciplinary Center for Earthquake Engineering Research (MCEER). Before joining MCEER in 1992, Friedland was a senior program officer with the National Academy of Science's Transportation Research Board, in charge of all bridge research conducted in the AASHTO-sponsored National Cooperative Highway Research Program (NCHRP). During his tenure with NCHRP, a number of major bridge initiatives were completed for AASHTO, including the development of the AASHTO load and resistance factor design (LRFD) bridge design specifications, *Manual for Condition Evaluation of Bridges*, *Guidelines for Bridge Management Systems*, and *Guide to Metric Conversion*. He has been a member of numerous national task forces and advisory committees, including those responsible for the development of Pontis and Bridgit. Friedland is a registered professional engineer and a member of the American Society of Civil Engineers (ASCE), the Earthquake Engineering Research Institute, and the Transportation Research Board. He serves on the Executive Committee of the ASCE Technical Council on Lifeline Earthquake Engineering and as associate editor of the ASCE *Bridge Engineering Journal*. Friedland received a bachelor's degree in civil engineering from Cornell University in 1977 and a master's degree in structural engineering and structural mechanics from the University of Maryland in 1978.

Dr. George Hearn (report primary author) is an associate professor of civil engineering in the College of Engineering and Applied Science at the University of Colorado at Boulder. Hearn's research is on condition assessment of highway bridges, uncertainty in assessments based on field test data, and the relation of inspection practices to condition rating scales. Hearn developed the translator for generation of U.S. National Bridge Inventory condition ratings from element-level condition data available in bridge management systems. Hearn earned a bachelor of engineering at The Cooper Union for the Advancement of Science and Art, and master's and doctoral degrees at the Columbia University School of Engineering and Applied Science. Hearn is a member of the Transportation Research Board (TRB) Committee for Structures Maintenance and the TRB Committee for Bridge Management Systems. Hearn is a member of the American Society of Civil Engineers (ASCE) Committee for Bridge Management, Inspection, and Rehabilitation, and is a past chair of the ASCE Committee for Safety of Bridges.

Dr. Jay Puckett (report facilitator) is a professor of civil engineering at the University of Wyoming and is also president of BridgeTech, Inc., a software development firm. He specializes in software related to bridge engineering and is a principal investigator/developer on AASHTOWare (Virtis and Opis). Puckett has bridge-research experience in software, physical testing, and specification development. He is a primary investigator on the National Academy of Science's National Cooperative Research Program 12-50 (Software Development Validation Guidelines). He holds a bachelor's degree in civil engineering from the University of Missouri-Columbia and master's and doctoral degrees from Colorado State University. He is a licensed professional engineer and also serves on numerous advisory boards and panels. His research interests include database and software development, bridge analysis, rating, and design. He was a founding editor of the ASCE *Bridge Engineering Journal* and is heavily involved with bridge engineering training. Puckett is coauthor of *Design of Highway Bridges—an LRFD Approach* (Wiley, 1997) and has published or presented more than 160 papers.

Richard Shepard is a supervising bridge engineer for the California Department of Transportation (Caltrans) in Sacramento, CA. Shepard manages the bridge maintenance and rehabilitation program for Caltrans, which encompasses responsibility for more than 12,000 bridges and expends an annual budget of about $200 million. Shepard's staff is also responsible for developing plans and specifications for bridge repair projects, and the structural analysis necessary to determine safe load capacities and other load ratings of bridges. Before assuming these bridge management responsibilities in 1993, he was the project manager for the FHWA's Demonstration Project 71, which developed the Pontis bridge management system. Shepard graduated from the University of California-Los Angeles and is a licensed professional engineer in California. He serves on several technical committees for the Transportation Research Board and is the vice chair of the AASHTO BRIDGEWare Task Force.

Todd Thompson is the special assignments engineer for the Office of Bridge Design in the South Dakota Department of Transportation. Thompson manages the State's bridge management system, Pontis, along with bridge load rating systems, Virtis and BARS (the Bridge Analysis and Rating System that Virtis replaced). Thompson serves on the department's technical panel on developing and implementing an automated permitting and routing system. He serves on the AASHTO BRIDGEWare Task Force as a Pontis representative. Thompson has a bachelor's degree in civil engineering from the South Dakota School of Mines and Technology. He is a licensed professional engineer in South Dakota. He is a member of the National Society of Professional Engineers, and has served on the local, State, and national levels.

Ronald A. Young is the engineer/manager of the Alcona County Road Commission in the State of Michigan, where his responsibilities include management of Alcona County bridges. He is a member of the Michigan Critical Bridge Advisory Committee that annually determines priorities for Federal bridge funds available for replacing or rehabilitating Michigan's 6,400 local agency bridges. Young has participated on Michigan Department of Transportation committees on historical bridges, bridge management systems, and bridge inspection. Before joining the Alcona County Road Commission, he worked as a civil engineering consultant, where his duties included bridge condition evaluation, construction inspection, and design. Young holds a bachelor's degree in civil engineering from Michigan Technological University and is a licensed professional engineer in Michigan. He also serves on the board of directors for the County Road Association of Michigan, and is the president-elect of the National Association of County Engineers.

FINNCONTACT NEWSLETTER—VOL.8/NO.2/JUNE 2000

ANALYSIS OF BMS REFERENCE BRIDGES

In Finland, a set of about 120 bridges has been selected for regular special observation to improve knowledge of bridge age behaviour and durability. This reference group consists of bridges of different material and type, age and condition located throughout the country.

The research programme consists mainly of studies of concrete as bridge construction and repair material. Concrete chloride content and carbonation are of particular interest. Samples have been analysed in the laboratory and various non-destructive testing methods have been used. The collected information is used to improve age behaviour modelling in the Bridge Management System (BMS).

BACKGROUND

The Finnish National Road Administration (Finnra) started the Bridge Management System development in 1986. At that time there was no bridge inspection and damage data available in the Bridge Register database to create age behaviour models for BMS. The road districts have been carrying out regular inspections since the 1970's, but the information was not stored electronically.

In 1999 Finnra was maintaining 10 686 bridges and 2 763 culverts (span length ≥ 2.00 m) with a total length of 315 km, a total deck area of 3.16 million m^2 and an estimated replacement value of 18 billion Finnish marks (3 billion Euros).

The modelling of deterioration acceleration and age behaviour of these bridges is based on the information of damages gathered during the inspections. Because there was lack of information of this kind in the beginning, expert evaluations were made for getting the first age behaviour curves and models.

The inspection period of a bridge is about 4 to 8 years depending on the condition. Thus a set of 99 bridges and 23 culverts, which as a sample group represent the whole bridge stock, has been selected for regular special observations to improve both knowledge of bridge age behaviour and durability and modelling in the management system.

The reference bridges are also used to compare bridge maintenance costs and life span costs for different bridge types. The economical and structural suitability of different bridge types and materials for various purposes will be analysed to improve future bridge design.

The first large analysis of the investigation results was reported in the end of 1998. This analysis gives information especially on age behaviour of concrete as bridge construction material. Also recommendations for further research are given.

REFERENCE BRIDGE GROUP

General

The reference bridge group has been chosen as a purposive sample to represent the whole bridge stock in the country. The reference bridge group consists of bridges of different material and type, age and condition, geographically situated throughout the country. The reference bridge group is graphically described here only by the overall condition of these bridges (see Figure 1). Finnra, naturally, has statistical information e.g. about the material distribution, age distribution and maintenance class distribution of this reference bridge group.

Inspections and concrete core sample investigations have been made since 1992. All the 122 bridges were inspected at least once in 1997. The inspections were carried out according to a special inspection plan. The yearly reports give an estimate for the condition of the bridge structural parts for every inspected individual bridge. Also samples were taken for laboratory tests.

Surface deterioration which is usually preceded by map cracking is the greatest problem in the reference bridge group. These damages are mostly located in edge beams and substructures like retaining walls and wingwalls. Also erosion of front slopes and cones are often observed damages. More serious damages are cracking and water leakage among surface deterioration and reinforcement corrosion of concrete deck superstructures. The most usual damage in steel bridges is rusting: many of the steel culverts constructed in the 1960's are in a very bad condition.

Statistical reliability

The statistical reliability analysis proved that the reference bridge group is a fairly representative sample of the whole bridge stock.

The proportion of steel bridges is greater in the reference bridge group than compared with the whole bridge stock. There are plans to add some short spanned concrete bridges in the reference group.

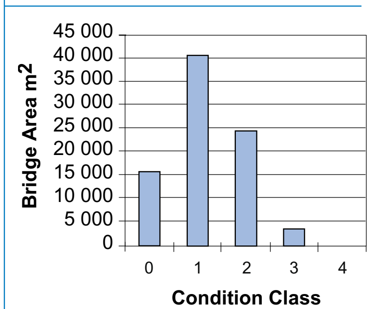


Figure 1. Calculated overall condition (0 means very good, 4 very bad) of the reference bridge group.

Figure 2. A core sample is being taken of one of the reference bridges near Kemi in Northern Finland.

INSPECTIONS

Investigations on the bridge site

The reference bridges have been inspected twice since 1992 for BMS purposes. The inspections are very similar to general inspections but they are carried out by a leading consultant specialised in bridge inspection and repair together with a bridge management expert from Finnra. The inspection interval varies with the research needs. Not all of the 122 bridges are inspected in a year, but every year bridges are inspected in different districts. The inspection interval for one bridge will be about two to five years.

The inspection data, bridge condition data and damage data are updated in the Bridge Register on the bridge site using a portable computer and a mobile phone connection. Non-destructive testing methods are used together with concrete core samples (see Figure 2) among others.

The following tests are used in the field investigations:

- Carbonation depth of the concrete is determined from core samples which are taken 50 mm corecase drill. The cores are cleft and phenolphthalein indicator sprayed on the cleavage surface.
- Acid soluble chloride contents of the concrete is determined using a Rapid Chloride Test equipment. The concrete powder samples are taken from the depth of 0 to 20 mm using a hammer drill.
- Concrete deck covers are measured using an electromagnetic covermeter (Proteq Profometer 4).
- Thickness of coatings in railings and steel structures are measured using Elcometer 245F.
- Concrete compressive strength is measured using the rebound Shmidt hammer (Proceed N).
- Relative humidity of the concrete is measured using Vaisala HMI sensoring elements and data logger.

All the tests are taken according to a plan made by the Technical Research Centre of Finland (VTT).

Also radar measurements for bridge decks can be used for bridges which are planned to be rehabilitated in the near future. The suitability of radar measurements was proved by a research programme in 1990-1993. The bridge deck surfacing, the protective course and waterproofing were opened up to the slab upper surface after the measurements. Comparisons with the radar results and empirical studies could be made and so valuable information gathered.

Tests in the laboratory

During the inspections, concrete core samples were taken for laboratory tests in VTT according to the sample plan. Altogether 112 cores were tested between 1992 and 1998. Carbonation depth, porosity and concrete compressive strength were measured from the core samples with a diameter of 75 mm. The samples needed in the tests were worked out of the cores as shown in Figure 3.

Also micro structure investigations were applied to a part of the cores. Concrete porosity, micro cracking, carbonation depth and possible ettringite occurrences were studied.

The following main quantities were measured:

- Total, protecting and capillary porosity of concrete
- Protecting porosity ratio
- Water penetration resistance factor
- Capillary factor
- Concrete compressive strength
- Concrete density and dry density
- Carbonation depth, minimum and maximum.

SAMPLE ANALYSIS

The samples were divided into groups by bridge structural parts according to location. The same bridge structural parts were used as in the Network Level BMS. Samples were divided into two environmental categories: structures exposed to sea water or de-icing salt and other structures.

Statistical analysis of the test results was made by calculating the mean values, deviations and numbers of tests of those quantities listed above. From this information a statistical reliability index related to the (0,1)-normal distribution was solved to give a probability of mean value deviation for the structural part in question, compared with all tested structural part samples.

The statistical analysis gives a quite exact description of the concrete used as a construction material in the Finnish bridges. Information on compression strength, porosity, density, carbonation speed and concrete cover of the reinforcement can be used when estimating bridge deterioration and remaining life.

BRIDGE AGE BEHAVIOUR MODELLING

Models Developed for the Network Level BMS

When creating the first bridge deterioration and age behaviour models there was not enough data of damages gathered during the inspections. Instead, opinion surveys (Delphi studies) and expert evaluations were carried out in order to set up the first age behaviour curves and models. One result from these expert evalua-

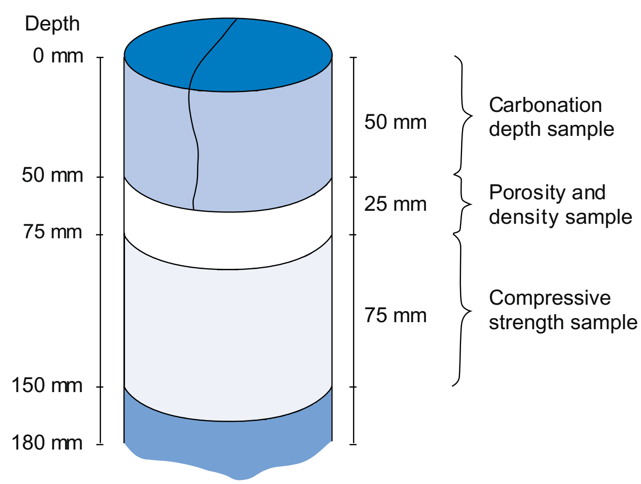


Figure 3. Partition of the concrete core samples for laboratory tests.

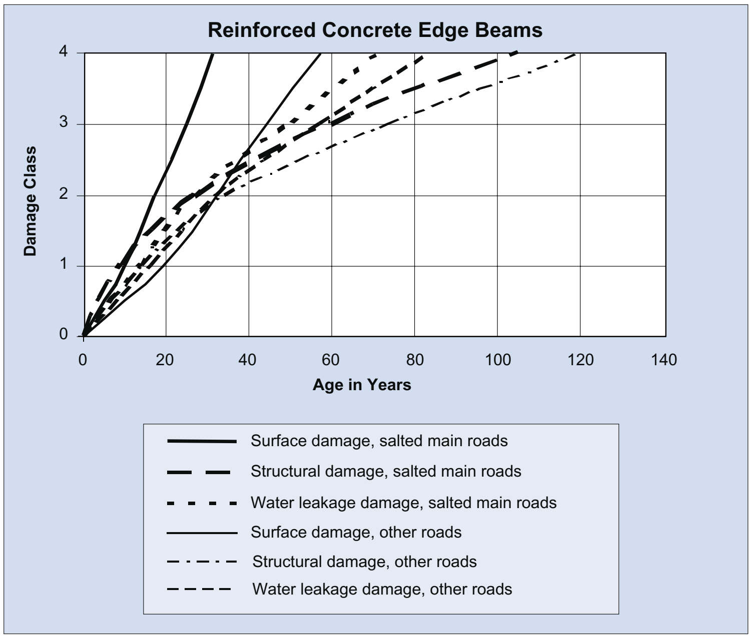


Figure 4. Age behaviour curves for reinforced concrete edge beams.

tions is given as an example in Figure 4. These polynomial curves can be presented mathematically as the following equation:

$$S(t) = a_1 [t / (1\text{-}k)] + a_2 [t / (1\text{-}k)]^2 + a_3 [t / (1\text{-}k)]^3 ,$$

where S is the damage degree,
t is the time in years,
k is the relative shortening on account of the parallel damage type,
a_1, a_2 and a_3 are constants.

Model Simulation

A research project on service life modelling of durability against freeze-thaw weathering and reinforcement corrosion of concrete structures was carried out in the years 1996 and 1997 in the Technical Research Centre of Finland, VTT. The goal was to develop a calculation method based on computer simulation for predicting the deterioration speed and service life of concrete structures in real circumstances and for getting knowledge of the effects of different material parameters and structural and environmental elements on the service life of the structures.

The simulation research was useful in developing new age behaviour models. Information on material and both damage and deterioration data from the measures gathered from the inspections and from research on the reference bridges were very suitable for the calibration of simulation models for the bridge management system needs. For this reason the simulation program was developed further in 1998. In the first phase, statistical mean values from the laboratory tests were used to calibrate the calculation models. The main models in the simulation program are among others:

- model for freeze-thaw weathering of concrete
- model for reinforcement corrosion.

Project Level BMS Model Development

To produce age behaviour models for bridge structural parts using the simulation program means that the empirical and experimental information from the reference bridges will be combined with the calculation formulas of the simulation program. The models can be easily calculated after this calibration.

The final age behaviour models for the Project Level BMS will be interactive. They can be adjusted by bridge material properties and structural and environmental information of a specific structure given by the BMS user. The user determines the bridge structure, location, chloride stress, concrete cover, concrete compression, porosity and width of the crack. If all the information is not available, the default models based on the research mean values of the reference bridge group will be used. In addition to this data the user can also specify the following deterioration information:

- The age of the bridge at the time of inspection
- Carbonation depth
- Critical depth of the chloride content
- Deterioration depth of the concrete
- Depth of the reinforcement corrosion in the crack.

The reliability and quality of service life predictions depend on the available bridge-specific information.

BENEFITS OF THE REFERENCE BRIDGE GROUP

The reference bridges are not only inspected by the experts but also separately by the bridge engineers in the road districts. So the reference bridge group serves very well as a data quality control method for the inspection data carried out by the bridge engineers.

The main target is to get improved age behaviour models for both the whole bridge stock and the main bridge structural parts on the network level and specified age behaviour models suitable for individual bridges on the project level . The first results from the analysis are very promising.

FURTHER RESEARCH

The research of the reference bridges continues. About 10 to 15 new bridges will be added on grounds of the statistical analysis recommendations. There are needs to special samples taken out of bridges which are mainly exposed to deicing salts or sea water and thus have a high chloride content. The models need new information in order to be improved continuously.

Investigations of the reference bridges have until now concentrated mainly on solving the basic properties of concrete and on studying the first stages of concrete damaging, that is, carbonation and chloride penetration. In the future, more attention should be drawn to the second stage damages like freeze-thaw weathering and corrosion which determine the end of the bridge life cycle. Also cracking surveys should be included in the future research programmes.

The steel bridges in the reference group mostly have a concrete deck. The steel superstructures, girders and especially culverts, will be investigated as its own group in a research programme in the near future. Timber bridges will have their own research programme, too.

For more information, please contact Marja-Kaarina Söderqvist, Finnra, P.O.Box 33, 00521 Helsinki, Finland; fax int. + 358 20 444 2512, email: marja-kaarina.soderqvist@tieh.fi.

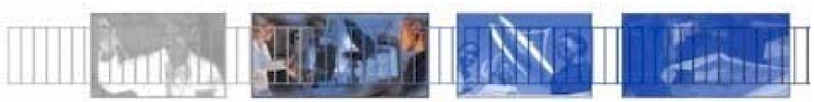
Ms. MARJA-KAARINA SÖDERQVIST, Finnra

APPENDIX C

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

CSIR

HOME



The CSIR is the premier technology and research organisation in Africa committed to innovation, supp
sustainable development and economic growth and creating value for clients, partners and stakehold

QUICK SEARCH

Go

MAKE A SELECTION

- Industry Sector
- Business Areas
- General Info
- e-Shop
- Staff Contacts

CSIR background

CSIR BACKGROUND (Council for Scientific and Industrial Research)

The CSIR (Council for Scientific and Industrial Research) is the largest community and industry directed scientific and technological research, development and implementation organisation in Africa and currently undertakes approximately 10 per cent of all research and development work on the continent.

As a key provider of information and technology solutions, the CSIR plays an integral part in the development of South Africa as a nation and the Southern African Development Community. It undertakes market-driven research and development and technology transfer:

- in support of its clients in both the public and private sectors
- to meet community needs and
- improve the quality of life of all South Africans
- in a cost-effective and ethical manner.

The CSIR (Council for Scientific and Industrial Research) is a statutory scientific research council established in 1945 and controlled by an Act of Parliament. Its aims, mission, basic research policies and priorities are set by the CSIR Board, whose members are appointed from the private sector by the Minister responsible for administering the Scientific Research Council Act, 1988. Executive responsibility for the organisation rests with the Executive Management, consisting of a President and five Executive Vice-Presidents.

Less than a decade ago, the CSIR set out to transform itself in the technology partner of the people of South Africa. From being almost completely dependant on government funding before the restructuring of the organisation in 1987, when its Parliamentary Grant income represented 70 per cent of total income, the CSIR has demonstrated its ability over the past eight years to steadily grow its external income as a contract research organisation and now derives close to 60% of external revenue from the private sector. The turnover for the CSIR group was in excess of R850 million in the financial year ending March 2001.

Executive responsibility for the organisation rests with its Executive Management Board, consisting of a President and Executive Vice Presidents responsible for the Finance and Marketing Services, Human Resources, Technology for Development and Technology and Policy portfolios.

The CSIR's eight operational divisions are responsible for its research, development and implementation activities that provide technology solutions and information across a broad range of technologies, such as aeronautical systems, building, communication, development, food, information, infrastructure, manufacturing, materials, mining, textiles and the environment.

E-GOVERNMENT INTEROPERABILITY FRAMEWORK

Executive summary

Better public services tailored to the needs of the citizen and business, as envisaged in the UK online strategy, require the seamless flow of information across government. The e-Government Interoperability Framework (e-GIF) sets out the government's technical policies and specifications[1] for achieving interoperability and Information and Communication Technology (ICT) systems coherence across the public sector. The e-GIF defines the essential prerequisites for joined-up and web-enabled government. It is a cornerstone policy in the overall e-Government strategy.

Adherence to the e-GIF policies and specifications is mandatory. They set the underlying infrastructure, freeing up public sector organisations so that they can concentrate on serving the customer through building value-added information and services. It will be for the organisations themselves to consider how their business processes can become more effective by taking advantage of the opportunities provided by increased interoperability.

The main thrust of the e-GIF is to adopt the Internet and World Wide Web specifications for all government systems. Throughout this section, use of the term 'system' is taken to include its interfaces. There is a strategic decision to adopt XML and XSL as the core standards for data integration and management. This includes the definition and central provision of XML schemas for use throughout the public sector. The e-GIF only adopts specifications that are well supported in the market place. It is a pragmatic strategy that aims to reduce cost and risk for government systems whilst aligning them to the global Internet revolution.

The e-GIF also sets out policies for establishing and implementing metadata across the public sector. The e-Government Metadata Standard will help citizens find government information and resources more easily.

Stipulating policies and specifications is not enough in itself. Successful implementation will mean the provision of support, best practice guidance, toolkits and centrally agreed schemas. To provide this, the government has launched the GovTalk website. This is a Cabinet Office-led, joint government and industry facility for generating and agreeing XML schemas for use throughout the public sector. Schemas can be found at http://www.govtalk.gov.uk/schemasstandards/xmlschema.asp. GovTalk is also used for wide consultation on a number of other e-Government frameworks and documents.

[1] The term 'specifications' used in the document includes standards approved by recognised standardising bodies. Where the specification refers to such a standard and alternatives are being offered as part of procurement, then purchasers are obliged by EC law to consider such alternatives provided they offer equivalent functionality.

The site also provides best practice guidance, FAQs, and advice on training and toolkits, and outlines the management processes.

The aims of the e-GIF will not be achieved overnight. The strategy needs to be managed as a long-term, ongoing initiative and must therefore be supported by robust processes. These processes, including the roles and responsibilities of key stakeholders, committees, management and working groups, are outlined in the document.

It is also essential to ensure that the e-GIF remains up to date, aligned to the requirements of all stakeholders and able to embrace the potential of new technology and market developments. The e-GIF introduces an Internet-based change management process which has been designed to engage and serve the stakeholder community in a dynamic way and to bring in innovations from industry on a global basis.

HIGHWAYS AGENCY RISK MANAGEMENT

HIGHWAYS AGENCY FRAMEWORK FOR BUSINESS RISK MANAGEMENT

January 2001

1 INTRODUCTION

DOCUMENT OBJECTIVE

1.1 This document sets out the Highways Agency's framework for Risk Management. It outlines both the Agency's approach to Risk Management and the associated roles and responsibilities of Agency colleagues.

1.2 The framework for Risk Management:

- is part of the business improvement programme and contributes towards the Agency's key objective number 8, 'to be a good employer, managing the Agency's business effectively and efficiently, seeking continuous improvement';
- relates directly to the Agency's Personal Development Plan competencies (number 8, problem solving and decision making);
- is a key element of the Highways Agency's ethos for project delivery (see **Annex A**); and
- builds on existing arrangements for Risk Management within the Agency.

1.3 Ownership and responsibility for maintaining this document rests with the Corporate Risk Management Advisor.

POLICY STATEMENT

We shouldn't be afraid to take risks, even if that means risking failure...
[Prime Minister Tony Blair].

1.4 In line with the Modernising Government white paper it is the policy of the Highways Agency to promote the creation of a more innovative and less risk-averse culture, involving a move from risk avoidance to "well thought through risk taking".

WHAT IS RISK?

1.5 For this document, the following definitions apply:

- **Risk** is anything that could hinder the achievement of business goals or the delivery of stakeholder expectations. Risk can arise from failure to exploit opportunities as well as from threats materialising.
- **Risk Management** is the culture, processes and structure aimed at managing potential opportunities and threats to an organisation.

INLAND NAVIGATOR

Inland Shipping by David Hilling, Inland Waterway Association, May 2004
http://www.waterways.org.uk/library/waterways_mag/2004/may/inland_shipping.htm

Wynn's gear up for the Big Loads

Robert Wynn & Sons Ltd (RWSL) Inland Navigator recently completed two successful movements of abnormal indivisible loads (AILs) from Goole to a National Grid Transco substation at the Staythorpe electricity generating station on the River Trent. Each movement involved a single quad booster unit of 285 tonnes. They claim that this is the furthest inland penetration by water of units of this size. The 70-mile road route alternative would have created congestion over a three day period.

Not surprisingly, the move was welcomed by the Shipping Minister, David Jamieson MP the Department for Transport having funded the purchase and conversion of the vessel with a Freight Facility Grant. Loads in excess of 150 tonnes weight, 6.1m in width or 30m in length need ministerial authorisation for movement by road and the department is trying to get as many as possible of 400 such loads off the roads and on to water.

The Transport Research Laboratory is currently engaged on a project to identify the real cost of moving AILs by different modes and make proposals regarding best practice - Wynn's clearly hope that this will lend support to their claim that water transport provides the best environmental option in both physical and cost terms and should be used wherever it is practicable.

Following the Trent movements, Wynns took delivery of the 2211 deadweight tonne multi-purpose pontoon (MPP) Terra Marique from the Dutch shipbuilder Damen. This second larger vessel that can operate in tandem with Inland Navigator in moving AILs from point to point on inland waterways, along the coastline and even across the Irish Sea, North Sea or English Channel if required.

Terra Marique is a sea-going barge 80m long and 16.5m beam and Inland Navigator can be docked inside her, thus enabling Inland Navigator (and any load she may be carrying) to be transferred along the UK coastline between various inland waterways. The Department for Transport, provided an £8.5m Freight Facilities Grant that covered 99% of the funding for the construction of Terra Marique and the conversion of Inland Navigator. RWSL, in turn, operates the two vessels on a 'non-profit' basis.

Because she is also designed to be able to provide a stable and static floating platform, she has considerable potential in the field of bridge construction and repair. For example, where whole sections of road or rail bridges over waterways need to be transported, then erected or replaced. It is believed that Terra Marique will substantially reduce both time and costs and minimising disruption to the travelling public and to freight.

She has been designed to load cargo in a number of different ways including lift-on, lift-off, roll- on, roll-off and by operating as a semi-submersible craft, not only Inland Navigator but other smaller vessels can be floated in and out of her 67m x 9m single hold for transportation.

End Notes

[1] Ministère de l'Équipement, des Transports, de l'Aménagement du territoire, du Tourisme et de la Mer (Ministry for infrastructure, transport, spatial planning, tourism, and the sea)

[2] Direction Départementale de l'Equipement (DDE), an agency of the Ministry of Equipment.

[3] IQOA stands for Image de la qualité des Ouvrages d'ART, or Image of the Quality of Bridges, Walls and Tunnels.