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Seminar 6

Bridge Management Systems

Systèmes de gestion des ponts

Brückenunterhaltungssysteme

Organizer:	Aleksandar Pakvor, Yugoslavia
Chairman:	Y. Fukumoto Japan

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Introduction to Bridge Management Systems

Introduction aux systèmes de gestion des ponts

Einführung in Brückenmanagement – Systeme

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SUMMARY

The paper is an introduction to Bridge Management Systems and the newest developments and trends. The following subjects will be briefly discussed: data bases; inventory; inspections, condition rating systems, deterioration models; maintenance; rating; ranking, priorities, optimization with limited funds; repair, rehabilitation, replacement; predictions of future needs (short term – long term); routes for heavy trucks, service information for road users; future developments.

RÉSUME

Cet article expose les données de base des systèmes de gestion des ponts, ainsi que les mises au point et les tendances les plus récentes dans ce domaine. Il traite les points suivants: banques de données; inventaire; inspections de contrôle, systèmes d'appréciation des conditions, modèles d'altération; entretien; évaluation; classement par rang, priorités, optimisation avec des fonds limités; réparations, rénovations, remplacements; prédiction des besoins futurs (à court terme et à long terme); itinéraires des poids lourds, service d'information pour les usagers; developpments futurs.

ZUSAMMENFASSUNG

Als Einführung in neuzeitliche Systeme für das Brückenmanagement werden eine ganze Reihe von Punkten ausgesprochen, wie Datenerhebung und -verwaltung, Inspektion, Beurteilungssysteme und Schadenentwicklungsmodelle, Prioritätenauswahl bei begrenztem Budget, Reparatur und Ersatzbau, Prognose zukünftiger Anforderungen und Verkehrslenkungsmassnahmen.

INTRODUCTION

In many counties, 70 % or more of the bridges have been built over the last three decades. To maintain these bridges in acceptable condition now requires more effective inspection processes, maintenance and repair. The right investment made now means lower total costs and thus savings in the long term. Through a bridge management system you can identify bridge needs and establish priorities. BMS systems must have activities described in manuals and with a standard terminology. BMS must coincide with the agency's policies, long term objectives and budgetary constraints. But a good BMS-system will vary from agency to agency depending on the specific requirements and preferences, environmental considerations, the traffic pattern and the national way of doing things. Even though the BMS structure may vary there are some basic elements that do not change. I will try to present some of these elements and speak about developments as I see them, based on 15 years work with the ideas behind BMS-systems and discussions with colleagues from many countries.

Data banks

The data banks are the foundations of an effective BMS-system and a computerized data bank is necessary for effective handling of the large quantities of data, if you have more than 200 bridges. The data banks must be very carefully planned. Too much data can spoil a good system. All data banks need updating and this costs money. You must decide what kind of models and analysis you want in your system, and the data requirement must be established before the data base is designed and programmed. Only information that will be used in the managing process must be stored. Standardization of data, simplicity and easy access are the keywords. It must be possible to add and remove data and to adjust or extend the system easily. Based on experience, you must be able to develop your bank - and in fact the whole edp-structure. Ways of data collection, sorting orders and information search paths must be thought out. Data groups can include administrative data, condition data, maintenance data, cost data, load capacity data and so on. The trends in the contents of the data banks, as I see it, are:

- more data from inspections
- more data for planning of maintenance
- more data for prediction of deterioration, data that describe the effect of different activities
- more economic data for budgetting.

The necessary work for analysis and programming of a prototype data bank and system varies from 5 to 10 man-years. This includes the handling of data from the inventory, the inspections and maintenance work.

The inventory

The inventory data normally are:

- data for identification
- data for location information
- data for administrative information
- data for technical information
- data for management of heavy trucks.

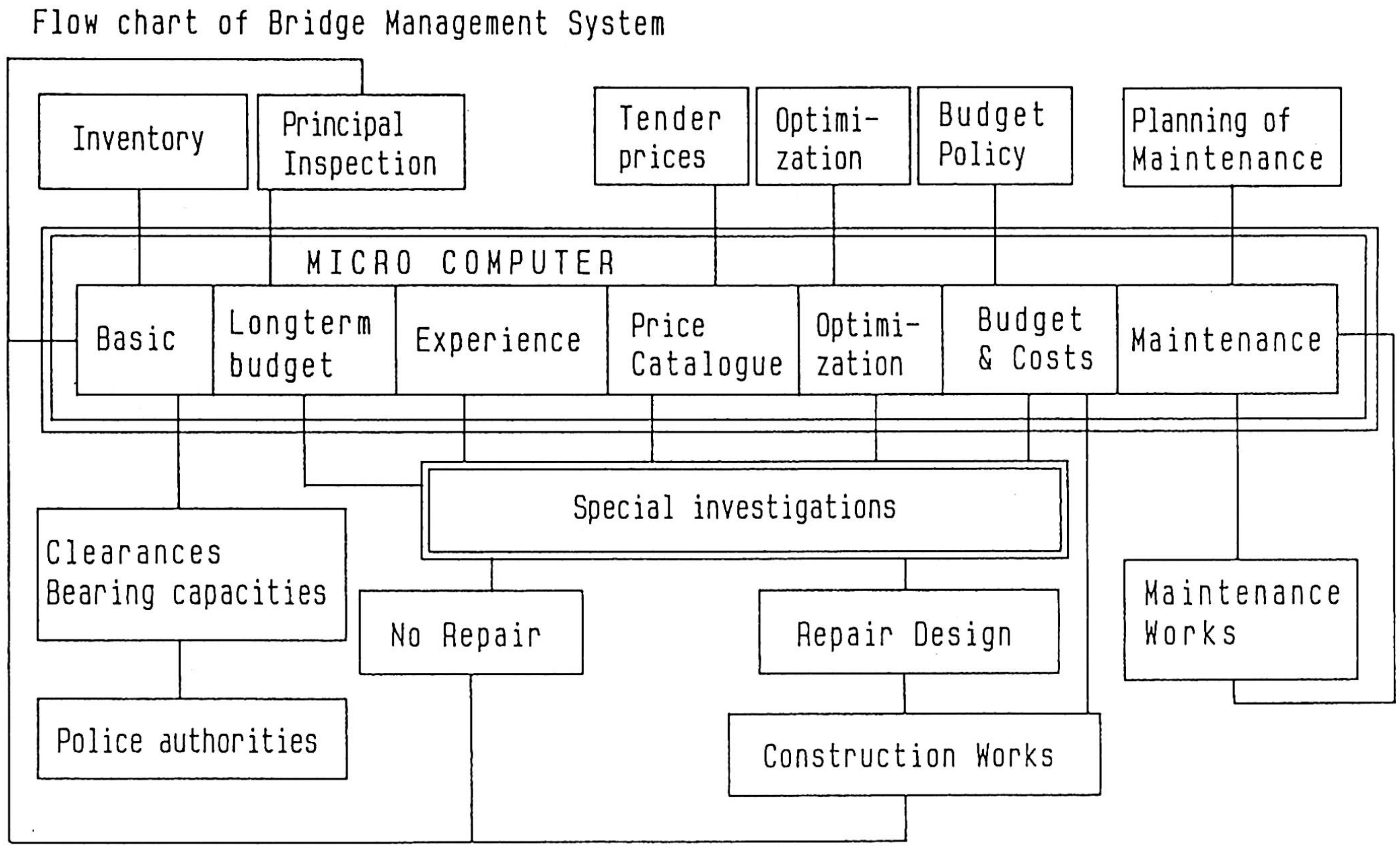

Fig. 1: Interrelated activities.

The inventory must always be kept up to date. Again, bear in mind that you should collect only necessary data, data you will use. The aim is to keep the amount of data to a minimum.

The inspections

In a BMS-system all activities must be based on the results of inspections. Normally, there are three kinds of inspections: superficial inspections, principal (general) inspections and special inspections. All kinds of inspections must be described in manuals.

Superficial inspections are done continuously together with the inspection of roads. It is a visual inspection, carried out by technicians. It controls the routine maintenance and ensures that nothing unforeseen has happened.

A bridge is given a **principal inspection** every 3-6 years depending on its condition and the type of construction. It should be carried out by trained engineers with a knowledge of structural mechanics and material properties. A bridge inspector can be responsible for 600-1000 ordinary bridges. All the data for the condition rating must be standardized and described in the manual. Condition rating systems for bridges and components have been developed in many countries using a numerical code, for example from 0 - 9 or from 0 - 5. You must obtain a uniform evaluation for all the bridges. In some cases you need engineering judgement. Often inspections also contain data on standardized maintenance or repair works and the amounts of different kinds of work. A sub-system can include standard costestimates for each maintenance type and can automatically calculate the total maintenance costs, when the inspector has described the types and the amount for each type. The sub-system may also produce tendering documentation for maintenance works.

Principal inspections are often visual. Development of inspection methods, easy and cheap, especially non-destructive methods, is needed. Fortunately many are making great efforts to develop these tools for practical use, for instance measurement of electrical potential, vibration analysis, ultrasonic tests, infra-red photography, radiography and radar. Perhaps we should also equip our bridges with monitoring instruments for inspection. There are already some examples of this; corrosion-cells could be mentioned. New technology on computer-automated bridge inspection is under development. You must describe the minimum conditions that will be acceptable from an operational and safety standpoint. These minimum conditions must be accepted by the politicians. Conditions below the minimum thresholds must trigger an immediate action.

If a principal inspection reveals a need for repair or rehabilitation it must be followed by a **special inspection.** Special inspections must be done by experts, consultants, and with the use of laboratories if needed. It is important to determine not only the nature of the damage but also its cause. The collected data must be standardized and some of it put in a "feed-back" module of the BMS-system. We hope to develop some deterioration models based on collected data and our experience over the years. But remember that these data give a prognosis based on the practice of the past and not the practice of the future. Judgements based on expected developments of the practice have to be added. The result of a special inspection must be a description of the damages and its causes, predictions of the future behaviour of the bridge, its remaining life and various repair strategies.

Maintenance

Based on the inspection results you can plan the maintenance works. If you have standardized the different types of maintenance or minor repairs, the BMS-system may calculate the amount of each type, the total costs, print working-orders for the personnel, or produce documents for tendering.

We know that some maintenance has to be carried out as a running routine to achieve the desired economic life of bridges. Add to that many works with level-of-service concepts with defined maintenance thresholds as a basis for budget allocations. Modern principles for quality assurance and certification must be considered Estimated maintenance costs must be considered as the necessary "basisfunds". Funds for repair, rehabilitation and reconstruction are needed in addition.

Predictions of future needs for repair, rehabilitation and reconstruction

In connection with the inspections you need to make an estimate of future needs at the project level, and also at the network level. You also need to predict the **service life** and the economic life of the bridges. Service life depends on structural adequacy (often 50-100 years) or functional adequacy (perhaps 25-50 years). The economic life we define as the period after which investment in maintenance, repair or rehabilitation does not "pay-off" compared with the investment in a new bridge.

Life-cycle cost models at the project level resemble well-known models for making investments, where you compare alternatives over time and calculate the rates of return. You convert future to present values using a discount rate and select the best alternative with the lowest costs. The question whether to rehabilitate or replace can be decided from the curve in fig. 2. It is simply the sum of first costs plus a discounted future replacement cost.

Rehabilitation will often be attractive compared with replacement. It is important that we are able to improve our rehabilitation methods. The savings for society can be tremendous. We also know that an investment of 1 unit in preventive maintenance or repair can result in savings of 2 - 4 units, because of an extension in service life or postponed rehabilitation. But the development of expert systems for the assessment and choices between technical solutions, products, intervention frequencies etc. is much needed. It is hoped that the use of BMS-systems can create the background for this.

Some **deterioration models** have been produced, but deterioration modelling is complex and a large number of factors are involved. The curves so far produced have not yet reached the stage and the detail needed. Fortunately, research and development concerning these matters have been started up in many countries. Various techniques, either statistical or stochastic, have been applied to predict bridge conditions. Markov chain and Monte Carlo simulation

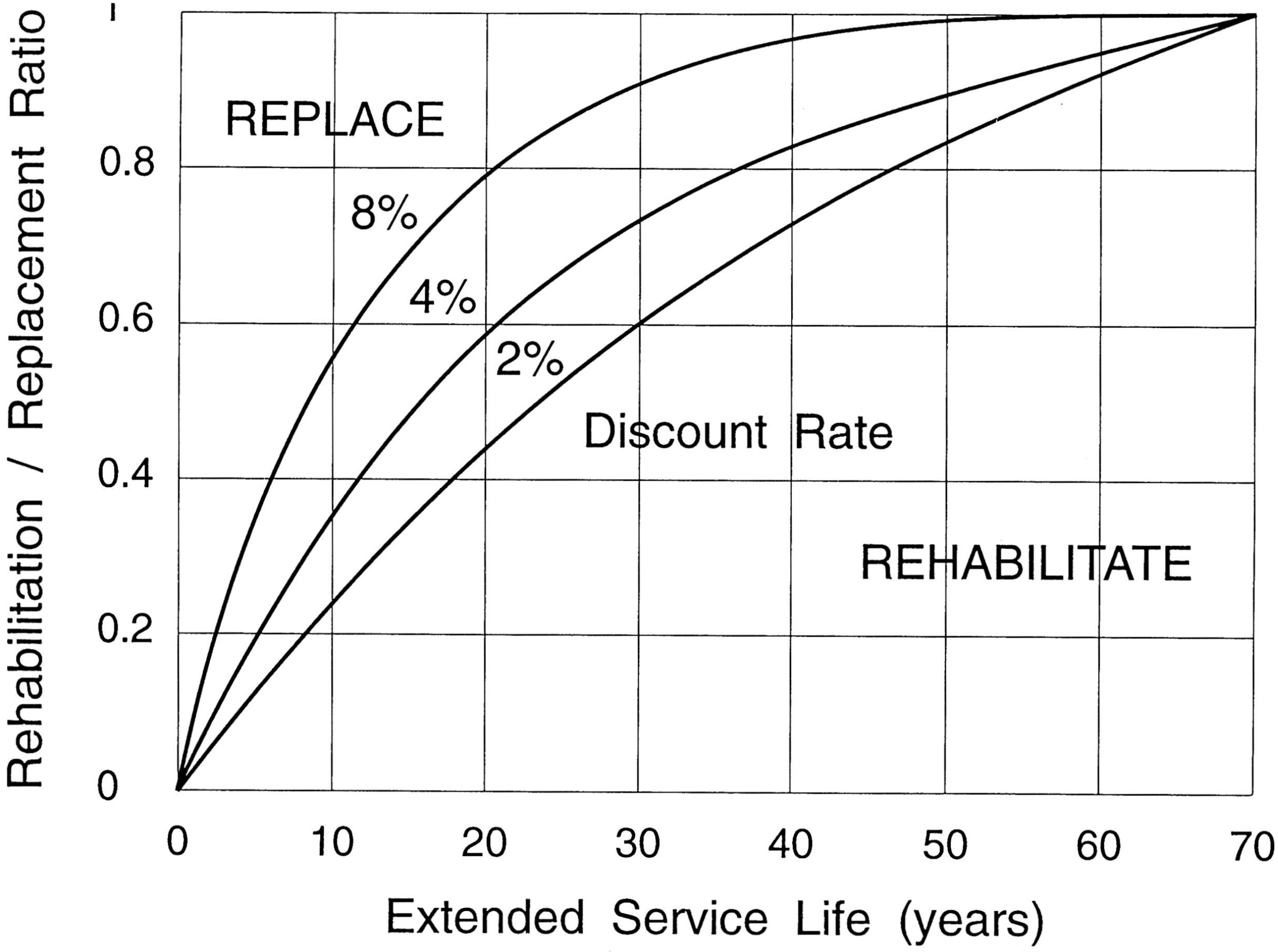

Fig. 2. Life-cycle cost comparisons

techniques could be mentioned. I find the present techniques a little bit too "theoretical" for practical use. I have more confidence in the hard way - to collect data on each bridge and to make an analysis based on data for the whole bridge stock. It must be emphasized that the prediction of bridge deterioration and the estimation of remaining service or economic life are important for the optimization process in bridge management. Budget planning for the short and long terms must describe the needs for funds.

Rating - ranking

Through the inventory and the inspections and investigations you have rated the bridges and have established a background for decisionmaking - whether to repair, rehabilitate or to do nothing and then reconstruct. In the calculation for each alternative you must include road user costs. The uninterrupted traffic flow is in focus. Possibilities for minimizing the disturbance to traffic may be the decisive factor.

Budget needs usually exceed the available funds. Therefore you need to rank your needs - you must describe your priorities. It must be done with a network model that considers alternative treatments for every bridge in the network compared with alternative treatments for other bridges to determine what can be accomplished with limited funding. The model can be based on purely economic criteria. The highest priority is given to work for which a postponement would result in the greatest cost increase. Other criteria can be used if desired, e.g. load carrying capacity problems, classification of roads in order of importance, military considerations etc. There have been attempts to make "multi-year analyses", where bridge conditions, traffic factors and budgets are analysed over a planning period. The analyses consider the short and long term costs for the various courses of action and their effect on future conditions.

Routes for heavy transports

As a part of a BMS-system there can be module for handling heavy transports. Load bearing capacity must be reviewed after each principal inspection. The bearing capacity of bridges must be classified in a uniform way for comparison with a similar classification of heavy trucks. By making a classification system both for bridges and trucks, you can manage the heavy trucks and the necessary permits and avoid overloading as much as possible.

BMS-systems are also a tool for better service to road-users. Quick route-planning for very high or wide transports is possible. In fact you can improve the answers to all questions concerning bridge data through easy access to data and the possibility of making an analysis.

Future development and trends

Future development and trends for BMS-systems, as I see it, will include:
- development of "level of service" concepts
- graphic data, documents, drawings and photos in the data bank in digital form
- use of probabilistic models
- more research and development on maintenance, repair and rehabilitation

- development of non-destructive testing methods
- instrumentation of bridges
- development of expert systems based on data and results from the use of BMS-systems.

The forum of European National Highway Research Laboratories, in its Strategic European Road Research Programme (SERRP) has proposed the following subjects as being of special importance for further research:
- standard methods of load capacity testing
- life-cycle cost models related to different structural components
- deterioration models for structures
- methods of maintenance or replacing trafficked bridges
- strategies for bridge repair and optimization of budgets.

In the past, bridge management often consisted of decisions made on a case-by-case basis at the project level.

In the future we must work at the network level, and consider the data and condition of the entire bridge stock. BMS-systems can bring us into a position to do this.

Final remarks

If you want to start up a BMS-system my advice is: "Think big - but start small". Be sure that you can operate the system, so that it is continuously updated. Then you can add more and more modules to the system and at the same time develop your organization and staff. If you want it all at the beginning, you will probably fail.

The real engineering challenge and the major benefits for seciety lie in the many questions concerning the correct handling of maintenance, repair and rehabilitation and not so much in the further optimization of construction disciplines. I hope that more and more engineers and researchers will realize this.

We are still searching for a lot of answers and I hope that this seminar will be a help for us all in finding some of them.