Capacity and repair index in railway bridge management in Finland

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Summary

The goal of maintenance of railway bridges is to control the condition of bridges and ensure the safety, use and the load capacity of bridges and preserve the bridges as a well kept part of the railway environment. Bridge management is needed to reach this goal as economically as possible. One of the biggest challenges for the maintenance manager is to be able to show to the owners of the bridges and the budget makers the need for bridge maintenance and repairs. As important is to show them that they really are getting results with the investments they have made.

The railways face great challenges due to the need for heavier axle loads and higher train speeds. This means that older bridges are used to their design limits. The Finnish Railways have achieved good success in using capacity and repair indexes to monitor the condition level and to target the repair actions to reach the most economical results.

Bridge management, capacity index, repair index, design age, bridge inspections

1. Railway bridges in Finland

The Finnish railway network had 2142 railway bridges at the end of year 2002. These bridges, along with 106 over passing road bridges, are owned by the Finnish Rail Administration.

The average age of the railway bridge superstructure is 33,5 years. The majority of railway bridges have been built after 1950 and bridges in the large age groups are beginning to need repairing. This is why the need for repairs and the need for more exact management will probably increase in the years to come.

The service life for railway bridges is very long. The railways have developed with great steps which means that old bridges have been designed to very different requirements than current traffic demands. The increase of train speeds and axle loads will have a large impact on the costs of maintenance and renewal of bridges.

Also the nature of building and repairing railway bridges differs greatly from other civil engineering structures. Bridges are built and repaired without any major disturbances of train traffic and with very high safety requirements. This causes that construction methods must often be chosen based on reduced design age targets and on what is possible on terms set by trains. The life time cost effects of the methods used have not been high priority issues during design, which in some cases unfortunately means that continuous monitoring and maintenance actions are needed to preserve the level of quality.

2. The maintenance management of railway bridges

According to present standards, the target for the service life of new bridges is 100 years. In the past, bridges had no designed service life targets. The service life of old bridges has to be defined with well planned inspections programs.

Maintenance is needed to meet these service life goals by controlling the condition of bridges, by ensuring the safety, use and the load capacity of bridges and by preserving the bridges as a well kept part of the railway environment. Bridge management is needed to reach this goal as economically as possible.

The railway bridge management system in Finland is an expert service produced by Railway Consulting of VR-Track Ltd.. The management system covers the bridge register, bridge inspections and programming of repair actions. The management service also includes an annual Railway Bridge Management Report to the Rail Administration. This report is then a strong base for financial decisions.

The Railway bridge Management Report include general bridge data, the final report of inspections done during the year and a presentation of the condition level of rail network bridges. It also includes cost estimates and proposals for repair action schedules.

3. Bridge inspection program

The most important tool for the management of railway bridges is the main inspection. These inspections are executed every 7 years. The inspections are mostly based on visual perception.

Experience has shown that best results are achieved when the inspections and programming of repairs are strongly linked together. The benefit is that the management engineers have personal and commensurable opinion about the bridges and they can personally guarantee the safety and use of the bridges. Other advantages include the reliability and comparability of the inspection results as a small group is in charge of the inspections. Also the information leak is minimised.

Not enough emphasis can be given to the information received during these inspections from maintenance personnel, users and neighbours and the changing of opinions to maximise the knowledge into use. The role of the inspections and management of bridges is also to pass information and ideas into use in new projects and standards.

In addition to the main inspection, the maintenance personnel executes a yearly inspections to the bridges. The goal for these inspection is to confirm the condition level and to guide basic maintenance actions.

The bridges, that are seen to be in poor condition, are assigned to a special inspection. Special inspections are done to get more exact information for repair design. These inspections are executed by special inspection consultants or research institutes.

4. Repair index

Earlier maintenance management and the programming of repairs have been strongly experience based. Problems with railway bridges were handled as an internal matter within the railways. Today the railways are linked to other elements in society and economical maintenance with the available financing must be better defined. This means that the need for repairs must be shown and that result must be made visible to financial people.

The first step to achieve this goal was taken as all damages and deficiency were graded into damage and urgency classes. During the past 15 years great steps have been taken as the introducing of the bridge database made it possible to handle large amounts of data.

Since 1996, a repair index has been calculated to railway bridges using the damage information. The repair index is a function of damages and repair urgency classes. The index is calculated for every bridge separately and with the index, the railway bridge repairs are set in order of priority (*Fig 1*). The index also forms key ratios for the continuous monitoring of condition levels.

The repair index emphasises the severest damage and all other damages have a weight 10 %. The realisation of repairs is never directly in the order of priority due to strategical, economical or other

reasons. Severe damages always raises the index significantly, which guarantees that a bridge with a high index stays on lists as long as they are repaired.

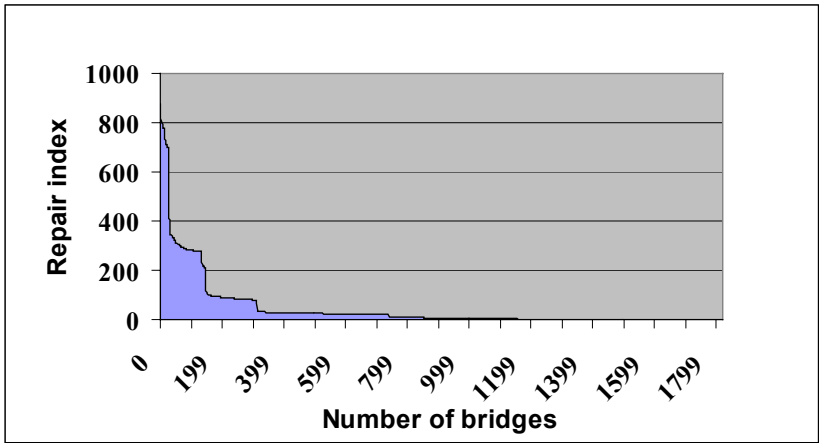

Fig. 1 The distribution of repair index of railway bridges.

The presentation of bridge condition levels can be illustrated with the repair index in many ways. Besides the list of priority, the bridges can be evaluated into condition grades. The repair index can also be used to evaluate trends in aging as well as the effectiveness and sufficiency of maintenance actions. Monitoring key ratios and linking costs with the repair index improves possibilities to make estimates on future financial needs.

In the year 2002, 320 bridges were inspected in two districts in the Eastern parts of Finland. For the first time repair index was used to compare data from two inspections. The comparison showed that the level of condition in the Pieksämäki District was successfully maintained with sufficient repair investments. In the Joensuu District repair investments have been smaller than the aging of bridges had required. It was also surprising that the speed of aging had previously been well underestimated.

On the Finnish railway network, the repair index shows that 6,3 % of the railway bridges are in bad or extremely bad condition. It had risen from 5,8 % in 2001. The total repair index sum of railway bridges at the end of year 2002 was 86291 points (34,4 points/bridge). The average last year was 34,5 points/bridge. A goal has been set that all bridges with repair index of over 140 shall be programmed for repairs within one year.

The Rail Administration has used yearly about 2,5…3,3 Mill.€ (0,5-0,8 % of the value of bridges) on bridge maintenance. The estimated costs of maintenance are based on the unit costs used generally in repair works in Finland and bridge repair plans. Mainly the costs presented do not include the work that is demanded on bridges to achieve the required level for higher train speeds and higher load capacity.

The total costs if aimed maintenance level is to repair (change from estimate of year before):

- all damages 41,85 Mill.€ (+ 21,6 %)
- all damages that repairs are recommended to 21,52 Mill.€ (+ 11,3 %)
- bridges, repair index over 150 10,49 Mill.€ (+ 48,1 %)
- bridges, repair index over 300 7,39 Mill.€ (+ 81,2 %)

For the next years, it is recommended in the management report that a yearly amount of 4,5-5,0 Mill. €, including basic maintenance, is used on bridge maintenance. The level of financial needs has risen due to several costly estimates of repairs to larger bridges and the risen costs of painting steel bridges. Also track network strategies have had a larger impact on bridge repair cost estimates [1].

Experience and feedback of the repair index from clients and users has been very positive. The repair index has proved to be useful tool to illustrate the efficiency of the continuing repair work on railway bridges and control the condition level. At its best it is also a cost very effective management tool.

5. Capacity index

The load capacity of old bridges depend on two factors: which design load and which material standard was used in the design of the bridge (*Fig. 2*) and how much traffic has crossed the bridge during its service life.

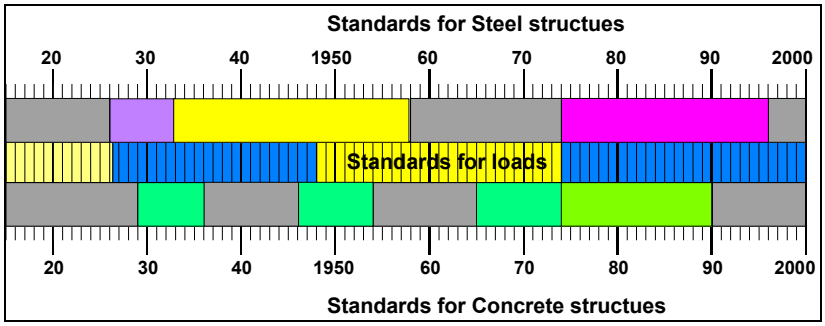

Fig. 2 The DNA of Finnish railway bridges.

The Finnish railway network capacity strategy includes the use of 25 and 30 ton axle loads. The oldest bridges still in use were designed and built around 1900 for much lower requirements. The load capacity of these bridges is determined by comparing the effects of 25 and 30 ton axle loads to the used design standards.

In general it can be said that possible risk bridges and risk structures are old and short-span bridges, secondary beams of steel bridges and old stone abutments.

Railway Consulting of VR-Track Ltd. has developed a capacity index to evaluate the risk bridges indicatively. As with the repair index, the capacity index makes it possible to draw up a priority list of bridges in risk order (*Fig 3*). The purpose of the capacity index is to find the most risky bridges and guide the required measures and focus the actions to them.

The capacity index takes into account the design loads and safety factors in the concrete and steel standards. The index does not take into account the condition of the bridge or the true strengths of materials, although material aging is one estimated factor in calculation of the index.

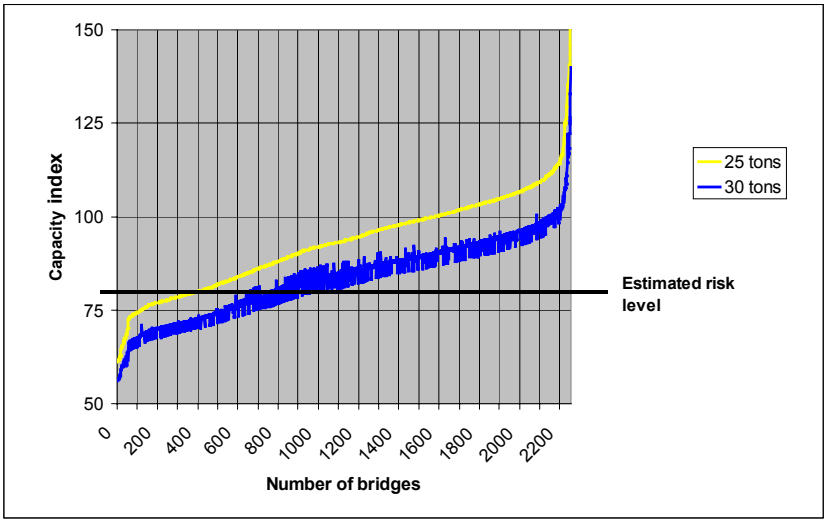

Fig. 3 The distribution of the capacity index of railway bridges.

The exact level of risk cannot be evaluated with the risk index. The permissible risk level is yet to be determined. The estimated risk level of the index is set by comparing the data with national and international studies. The selection of the risk level has a great effect on the number of risk bridges. Uncertainties before the use of higher axle loads can be eliminated only by calculations based on measurements of structures and materials. The repair index narrows down the number of risk bridges and so economical solutions and decisions can be reached cost efficiently [1].

6. Conclusions

Experience has shown that there are four key points for the successful management.

A good inspection program is a must for effective maintenance management. Without continuous monitoring and analysing of data it is not possible to know the condition level. Inspections must be planned so that data is usable for further analysis. Earlier inspections are done and the results were documented, but the documents were filed and forgotten. The possibility to use reliable indexes depends on long-span plans for the inspections.

Secondly as the future of repair investments do not show any signs of growth despite the growing needs, the costs have to be well defined. It is up to the engineers to sum up the information and make priority lists to help financial decision making. For this the repair index and the capacity index has been developed. As important is the continuity of the monitoring and the indexes have proven to be a useful tool to follow the large amount of data. The engineering problems must be translated and introduced as simple as possible.

The third key point for successful management is to translate damages and needs into the universal language of costs. Engineering problems must be presented as costs and investment alternatives. Every damage or deficiency has a repairing action which can be given a price tag. In Finland the costs are calculated by using unit costs or cost estimates of existing repair plans. This task is also a continuous process and requires long-span following. Costs are also very good indicators of trends together with the repair and capacity indexes. Alternative investment program proposals give budget makers vital information on how there decisions will effect the bridge condition level.

The fourth key point is that the management system has to be user friendly for users and cost efficient for owners. The indexes have proven to be very motivational to maintenance personnel. They can set there own goals of improving the repair index average. It is also very motivating for them to see how their actions effect the condition level and they can compare the numbers to other maintenance areas. For the owners it is important that they can see that their investments and decisions have effects on the results. The system has to concentrate on the on the results.

It is not a very big suprise in today's busy and competitive world that all information of studies and calculations must be presented on the bottom line. The indexes and the management system of railway bridges in Finland has had good experience in answering this challenge. The railways face new challenges and demands and the development of monitoring processes is a continuous work field.

[1] Wuorenjuuri J., *Railway Bridge Management Report 2002* for Finnish Railway Administration, Helsinki, Finland, 2003, 39 pp.