Improving Railroad Track Maintenance Scheduling with Operations Research Techniques

YANFENG OUYANG

The author is Associate Professor, Department of Civil and Environmental Engineering, University of Illinois at Urbana–Champaign.

CSX Transportation spends hundreds of millions of dollars every year on railroad track maintenance activities, routing large crews and heavy machinery throughout its extensive railroad networks. Effective planning saves on maintenance costs and resources and affects the safety and operational efficiency of the maintenance activities. Operations research techniques offer opportunities to facilitate and improve the decision-making process.

PHOTO: CSX

CSX track inspection.

Problem

The scheduling of track maintenance involves a series of highly complex activities. Thousands of miles of tracks must be inspected regularly to identify defects. The defects are grouped into projects, and each project comprises a workload suitable for specialized maintenance teams. The teams travel around the network to complete all projects, aiming at efficient travel schedules and complying with thousands of business rules, including technological and operational requirements.

The main outputs are a series of timetables that specify the inspection plan, the project composition, and the maintenance teams' travel schedules. Additional considerations include how many inspection or maintenance teams should be hired the following year, how the workloads can be balanced across teams, and the cost in resources.

Solution

Through collaborative research, the University of Illinois at Urbana–Champaign (UIUC) and CSX Transportation have developed a series of sophisticated models and tools to address these considerations. The problem was divided into three main parts:

1. Scheduling rail inspections (*1*),
2. Clustering jobs into projects (*2*), and
3. Scheduling maintenance teams (*3, 4*).

To schedule the inspections, the railroad network is divided into hundreds of segments. Each segment is inspected periodically to ensure the safety of train operations. The schedule specifies the activities assigned to each inspection team, as well as the starting times of the activities, so that all of the required inspections can be completed. The inspection teams must optimize their routes, to spend less time traveling between activities that may be far apart.

The model also satisfies a variety of business constraints—for example, the teams should not have to work during weekends and holidays, and no more than one team should be working at any time within a subdivision, which is the basic unit of analysis for traffic operations in the railroad network.

Clustering Jobs

Thousands of track maintenance jobs—such as the replacement of track components and other major repairs—are identified for maintenance teams to perform in the following year. The model clusters the jobs into projects, so that each project spans full weeks, because the machinery must be relocated on weekends, when the teams are not working.

Sometimes a maintenance team can work overtime at extra cost to reduce a project's duration. A major goal of the model is to minimize the total number of weeks needed to complete a project, reducing

PHOTO: CSX

Maintenance activities.

TABLE 1 Estimated Improvements for Full-Scale Implementation

Model	Performance Metric	Reduction (%)
Rail inspection scheduling	Travel distance	25.0
Job clustering	Total project duration	11.0
Maintenance team scheduling	Travel distance	13.6

the labor costs, and to select projects for overtime work. In clustering jobs, the model must accommodate many operational constraints. For example, clustering certain jobs in different subdivisions could cause difficulties in rescheduling train traffic.

Addressing Constraints

After the projects are created, the team assignments and schedules are determined. The routes of teams must be optimized to reduce the total travel costs between projects, as well as other costs that may arise. For example, certain projects may require additional devices and procedures in winter; multiple ongoing projects within adjoining subdivisions or in major corridors may block train traffic and should be avoided. The model addresses thousands of such requirements.

All of these problems are formulated into large-scale network routing and scheduling models with many complex constraints. These were solved by developing a variety of advanced operations research and optimization techniques with customized features. For example, the rail inspection scheduling problem was solved with a local search algorithm in an incremental scheduling horizon framework. The job clustering problem was solved with a multistep heuristic search algorithm. The maintenance team scheduling problem was solved with a multiple neighborhood search algorithm and mixed integer programming subroutines.

Application

The collaboration between CSX Transportation and UIUC on track inspection and maintenance scheduling started in 2008. The CSX Operations Research Department focused on providing business requirements and data, and the UIUC team focused on developing mathematical models and solution algorithms. The researchers held weekly teleconferences to update each other on the project's progress.

Experts from the CSX engineering department reviewed the solutions at every development phase; in addition, comparisons were made with state-of-the-art benchmark solutions. The UIUC researchers received feedback on model enhancements and modifications. This solution-and-review process was repeated throughout the project to ensure that the models were accurate and the results were implementable.

The CSX decision-support system incorporated the three main models between 2009 and 2011, and the results were impressive. The new modeling approaches proved effective, efficient, and suitable for full-scale practical use and have provided CSX with functional schedules. The success of this project also strengthened the collaboration between CSX and the UIUC Rail Transportation and Engineering Center.

Benefits

The performance of the implemented models, estimated for recent years of operation from the railroad's actual information, was compared with the state-of-the-practice benchmark solutions; Table 1 (above, left) summarizes the results. As shown, the models that were developed yielded better solutions in the three aspects of track maintenance scheduling. The inspection and maintenance team scheduling models reduced the total travel distances for inspection teams by 25.0 percent and for maintenance teams by 13.6 percent; the job clustering model reduced the total duration of projects by 11 percent.

The decision tools offer the advantage of working fast; for example, the solution time for the full-scale maintenance team scheduling problem formerly required one week under the state-of-the-art manual solution process; this has been reduced to only a couple of hours. CSX now can conduct a what-if analysis efficiently to optimize resource planning for material and manpower. These optimization approaches have helped CSX save millions of dollars in the past few years.

For more information, contact Yanfeng Ouyang, 1209 Newmark Civil Engineering Laboratory, University of Illinois at Urbana–Champaign, 205 North Mathews Avenue, Urbana, IL 61801; yfouyang@illinois.edu; or 217-333-9858;

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Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2952; gjayaprakash@nas.edu).