Detailed Inspection of U.S. Army Railroad Trackage and Application to Civilian Short-Line Railroads

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The U.S. Army Construction Engineering Research Laboratory has developed a railroad track maintenance management decision support system called RAILER. The detailed track inspection procedures are designed to implement the recently issued Army Track Standards in a manner consistent with the larger goals of RAILER, thus promoting both track safety and track maintenance management. The inspection procedures are divided into six track component areas, and field inspection forms have been developed that guide the inspector through the inspection of each component area. The inspection procedures include measures for dealing with track components that are hidden, such as by vegetation or road crossings. In addition to the Army Track Standards, the inspection procedures can also support other track standards such as those propagated by the FRA or designed by a private operator. This property serves to facilitate a transfer to the civilian sector. The inspection procedures also take advantage of the RAILER computer software to ease the overall burden of the inspector.

RAILER is a decision support system for track maintenance management developed at the U.S. Army Construction Engineering Research Laboratory (USA-CERL) (1, 2). It is currently being implemented at selected Army installations. Although primarily designed for Army use, RAILER was constructed to also facilitate technology transfer to the civilian sector for use by the commercial railroad community, especially short lines and industrial networks.

As a decision support tool, RAILER can be used, in part, to develop annual and long-range work plans, develop budgets, determine condition levels, and estimate maintenance and repair costs. RAILER uses personal computer-based software developed at USA-CERL to accomplish these tasks. The data base includes several information types, the most important of which are inventory and inspection. The inventory data elements are discussed in a paper by Uzarski et al. (3). The RAILER detailed inspection procedures are discussed here; a complete description of these procedures is presented in a USA-CERL technical report (4).

BACKGROUND

Commercial railroads are governed by the safety inspection requirements of the FRA (5). Individual railroad companies may also have their own inspection procedures for locating defects for maintenance planning. However, U.S. Army track networks do not fall under the auspices of the FRA, nor do Army track inspectors. Because of their varied duties and responsibilities, these Army track inspectors also do not have the same intimate knowledge of their networks as do track section foremen, track inspectors, and road masters in the commercial sector. Until recently, the Army's approach to track safety and track maintenance management was not very structured. Army track was divided into just two components for maintenance management—ties and trackage—and track inspection procedures were only generally described (6). Also, inspection intervals tended to be infrequent.

To facilitate efficient maintenance management of Army track and safe railroad operations, the Army has developed RAILER and issued detailed track maintenance standards (7). The standards serve the dual function of ensuring safety and identifying maintenance needs. The safety aspects are covered through the inspection frequency and the imposing of operating restrictions associated with certain defects. These operating restrictions are 10 mph, 5 mph, and "No Operations." Maintenance needs are determined through specific defect identification. Accordingly, the track standards provide a fundamental basis for track inspection and evaluation.

Many of the decision support tasks that RAILER is designed to perform require an assessment of track conditions, current and future. These conditions are determined by inspection with respect to the new Army Track Standards. While these standards are quite precise, they do not delineate specific inspection procedures. Such procedures were developed for RAILER. The inspection procedures outlined in this paper expand on and modify the previously documented interim detailed inspection procedures (1, 2).

INSPECTION PROCEDURE CHARACTERISTICS

The RAILER detailed inspection procedures were developed primarily to fulfill two interrelated tasks. The first is to promote safe Army railroad operations by incorporating the technical aspects of the U.S. Army Track Standards into practical procedures. Second, the procedures provide a means for capturing the defect information in a format that facilitates...
use within the RAILER system for track maintenance management. The inspection procedures have the following characteristics:

- The inspection procedures are divided into component areas consistent with the Army Track Standards and the RAILER inventory data elements (8).
- Thorough detailed field inspection forms are used to guide the inspector through the inspection of each component area.
- Procedures are included for dealing with track components that are hidden, such as by vegetation or road crossings.
- Although the inspection procedures are designed to capture all discrepancies with the Army Track Standards, the procedures are at the same time flexible and thorough enough to support other track standards (such as those propagated by the FRA).
- The inspection procedures take advantage of the RAILER computer software to ease the burden of the inspector.

These interrelated characteristics are discussed more fully in the following subsections.

**Inspection Component Areas**

For convenience, the inspection procedures are divided into six track component areas:

1. Tie inspection;
2. Vegetation inspection;
3. Rail and joint inspection;
4. Other track components inspection;
5. Turnout inspection; and
6. Track geometry inspection.

The components included in “Other track components” are the bridge approach, ballast/subgrade, car bumper, car stop, culvert, ditch, derail, drain, embankment, grade crossing, gage rod, hold down device, insulated component, rail anchor, rail crossing, signals, signs, shim, spike, storm sewer, and tie plate.

The inspection procedures primarily consist of specific visual observations and manual measurements of the track structure, which may be augmented by automated data collection for track geometry and for rail and joint defects. A complete regular manual inspection would include the first five component areas; manual track geometry inspection is usually conducted only when there are specific indications of potential problems. (Examples of these indications include visual observations and reports of rough riding from the engine crew.)

The segmentation of the inspection process by component areas permits significant flexibility. For example, a track may be inspected for only one or two components, or all components, depending on the purpose of the inspection. This flexibility also allows the order in which component areas and track segments are inspected to be tailored for the particular network layout. Such an inspection plan is illustrated in Figure 1. For example, with a single isolated loading track, it may be advantageous to inspect some components in one direction and other components while walking back. However, with two parallel loading tracks, it may be better to inspect some or all components of one track in one direction and the same components of the other track while walking back.

**Field Inspection Forms**

The inspection process is organized around five field inspection forms. One of these forms deals with three component areas: ties, vegetation, and rail and joints. A completed example of this form is presented in Figure 2. An explanation of various categories in this figure is given as follows:

- In the column for Inspection Impaired by Vegetation or Other Material, the inspector has entered four lengths of track where tie inspection was impaired. The lengths were 10, 30, 70, and 25 ft, respectively. Addition (+) signs are used to separate the lengths. The lengths are then totaled below (135 ft).
- The various tie defects are delineated in the columns. Hash marks are used to note defects and then totaled.

**Vegetation Inspection**

Vegetation growth is noted in feet of affected track. Results of the vegetation inspection were as follows:

- There were four occurrences of low severity (Growing in Ballast, Interferes with Walking, etc.) vegetation growth. The occurrences were 10, 50, 20, and 200 ft in length, for a total of 280 ft.
- A 50-ft length of vegetation growth prevented track inspection.
- No vegetation growth serious enough to interfere with train movements was found.

**Rail and Joint Inspection**

Rail and joint inspection found the following defects:

- All bolts were loose (ABL) in a joint in the left rail at Station 1 + 00.
- The end batter (ENB) at joints was greater than ½ in. in both rails starting at Station 1 + 00 and continuing over 10 joints.
- There was a broken or cracked joint bar (BCB) in the right rail at Station 2 + 20.
- Some joints had improper bolt pattern (IBP). Starting at Station 2 + 50 and continuing for 200 ft, about 50 percent of the joints had the improper pattern.
- Several lengths of inspection impairment were noted. Inspection was impaired for one quarter (one side of one rail) for an 8-ft length. For two-, three-, and four-quarters coverage, the lengths of impairment were 6, 8, and 4 ft, respectively. The line totals are then multiplied by the quarters of coverage to get the quarter lengths (Q.L.). The quarter lengths are then summed and divided by 4, which gives the equivalent length of complete inspection impairment.

These forms are designed to guide the inspector through a structured inspection process. This is especially well illustrated by the turnout inspection form (see Figure 3). Mastering the inspection procedure associated with using this form requires a minimal amount of training, despite the large amount of information that is collected. In this case, the four blocks
on the form lead the inspector through the inspection; the inspector simply has to fill in the various blanks and circle the appropriate responses.

The other inspection forms are presented in an abbreviated fashion in Figures 4 through 6. The form depicted in Figure 4 can be used to continue the visual rail and joint inspection (see Figure 2) or for automated rail inspection. Because many rail defects are not visible (and hence can only be detected with specialized equipment), the continuation form depicted in Figure 4 lists more rail and joint defects than the form depicted in Figure 2. When used with automated rail inspection, the continuation form serves as a data transfer medium between the commercially prepared report (list of defects) and RAILER.

The track geometry inspection form (see Figure 5) is generally only used for manual inspection. Automatically collected track geometry data can be transferred directly from the geometry test equipment onto floppy disks for processing within the RAILER system. An explanation of segments of Figure 5 is given as follows.

- In Segment 101, Station 5+50, the gage is 57.8 in.
- In Segment 101, Station 7+00, the crosslevel is +1.5 in. (using the left rail as reference), the alignment is 0.5 in. in both the left and right rails, the profile of the left rail is 1.1 in., and the profile of the right rail is 0.5 in.
- In Segment 101, Station 7 + 05, the crosslevel is +0.5 in. (using the left rail as reference).
- In Segment 102, Station 9+00, the alignment of the left rail is 1.1 in., and the profile of the left rail is 1.5 in.
- In Segment 102, Station 10+50 (in Curve 1C1), the gage is 56.7 in., the crosslevel is +2.0 in. (using the left rail as the reference), the left alignment is 4.0 in., and the right alignment is 4.0 in.

**Impaired Track Inspection**

Sometimes grade crossings or material, such as excessive ballast and vegetation, will interfere with track inspection. This can be a particular problem where seldom used tracks may...
FIGURE 2  Completed inspection form for ties, vegetation, and rail and joints.
**FIGURE 3** Completed turnout inspection form.
when it is implicitly and erroneously assumed that defects not seen (and hence not recorded) do not exist. Furthermore, even a few linear feet of foreign material may hide serious defects affecting the safety of railroad operations.

Inspection-impaired track is accounted for separately within the RAILER detailed track inspection procedures for each of three component areas: ties, rail and joints, and other track components. These are separated for two reasons. First, foreign material that obscures one component might not impair the inspection of another component. For example, rail and joints can often be easily inspected when the ties are covered by ballast or soil. Second, the nature and extent of obscuring foreign material that obscures one component might not impair the inspection of another component. For example, during the time between a foreign material may change between the inspection of two (which may be more than a month), gravel may have been accidentally spilled on the track, obscuring tie plates and spikes ("other track components").
FIGURE 5  Completed track geometry inspection form.

FIGURE 6  Completed other track components inspection form.
Ties are considered inspection impaired if less than half of the top surface is visible. The other two component areas use the concept of quarters for inspection impairment. For example, if the base on one side of only one rail is covered, then rail and joint inspection is one-quarter impaired. At the other extreme, four-quarters inspection impairment occurs when the base on both sides of both rails is covered. Quarters of inspection impairment are also used with "other track components"; the only difference is that the inspection impairment criterion is whether or not the spike heads are visible (instead of the rail base).

For each of the three component areas, obscuring foreign material is accounted for in terms of (equivalent) linear track feet and percentage of track length. These are calculated within the RAILER computer software based on data collected in the field during track inspection and can also be calculated manually if RAILER is not computer implemented. The field entries associated with inspection-impaired track are illustrated in Figures 2 and 6. An explanation of various categories shown in Figure 6 is given as follows:

- The ballast (component code: BS) is dirty (defect code: BAD) starting at Station 0 + 00 and continuing for 100 ft. This is not an immediate hazard.
- A culvert (CU) is clogged (defect code: OBF) so that flow is obstructed. The culvert is a discrete item located at Station 0 + 50. This is not an immediate hazard.
- Three gage rods (GR) are loose (defect code: LOS). The first loose gage rod is located at Station 0 + 90. This is not an immediate hazard.
- Some spikes (SP) are improperly positioned (defect code: IMP) because of an improper spike pattern. Starting at Station 1 + 40 and continuing for 200 ft, about 50 percent of the spikes are improperly positioned. This is not an immediate hazard.
- A spike (SP) is missing (defect code: MIS) at Station 1 + 50. This is not an immediate hazard.
- An embankment (EM) is experiencing erosion (defect code: ERO) starting at Station 2 + 10 and continuing for 20 ft. This is not an immediate hazard.
- A culvert (CU) has suffered structural deterioration (defect code: STD). The culvert is located at Station 2 + 50. This defect is marked as an immediate hazard, and the comment indicates that the track has "settled badly," which would lead to unsafe car movement (e.g., rocking) if the track is used.

Flangeway Measurements

- A grade crossing (component code: GC) that crosses Infantry Road has an effective minimum flangeway depth and width of 1.5 in. and 1.6 in., respectively. The flangeways are fouled.
- A grade crossing (GC) that crosses Parking Lot 5 has an effective minimum flangeway depth and width of 0.5 in. and 2.0 in., respectively. The flangeways are fouled.
- A rail crossing (RR) that crosses Segment 107 has an effective minimum flangeway depth and width of 2.0 in. and 1.9 in., respectively. The flangeways are not fouled.
- A grade crossing (GC) located at Track Station 4 + 60 has an effective minimum flangeway depth and width of 1.4 in. and 1.9 in., respectively. The flangeways are not fouled.

In addition to undesirable foreign material, grade crossings (paved areas) also obscure track inspection. Grade crossing length is a RAILER inventory data element. This data element is used within the RAILER software to account for the effect of grade crossings on track inspection. For this reason, the inspection impairment associated with grade crossings can be ignored during track inspection field procedures if RAILER is computer implemented. Otherwise, the effect of grade crossings is accounted for in the field in conjunction with undesirable foreign material.

This process quantifies, for each of the three component areas, the amount of track that cannot be properly inspected. Procedures for using this information to estimate the hidden defects are still under development.

Relationship to Track Standards

Track maintenance or safety standards describe desired or acceptable track conditions. In addition, track standards may indicate the relative severity of various deviations from these acceptable track conditions (as the Army standards do).

The first immediate goal of the detailed inspection procedures described here is implementing the Army Track Standards in a manner consistent with the RAILER program. However, RAILER is also designed to accommodate other track standards. For example, a version of RAILER is being developed for the U.S. Army in Europe that will incorporate German Track Standards. Also, it is envisioned that RAILER will be eventually transferred to the civilian/private sector for use by short lines, industrial networks, and possibly some branch line operations. These operators may wish to incorporate FRA or their own track standards.

In order to accommodate this flexibility, the inspection procedures are designed (as much as possible) to collect raw data, which are later compared within the computer with the appropriate standards (or possibly multiple standards). For example, instances of three consecutive defective ties are noted as raw data during tie inspection (see Figure 2). This defect implies a 10-mph operating restriction in the Army Track Standards. However, in some industrial situations, such as in a steel mill operation where eight-axle ladle cars regularly carry molten iron, management could elect to impose a more restrictive 5-mph limit, or perhaps prohibit all train movements, whenever three consecutive defective ties are encountered.

The analysis of the inspection data relative to a given set of track standards is provided in three RAILER "Comparison Reports" that vary in their level of detail. These are a Condition Summary, a Condition Comparison by Inspection Type (component area), and a Detailed Comparison. An example of the Condition Comparison by Inspection Type report is presented in Figure 7. The comparison results can be tied to a locally developed maintenance policy so that a Maintenance and Repair (M&R) report can be generated for work planning. This report can be generated in two levels of detail, an M&R Summary and a Detailed M&R. An example of the summary level is presented in Figure 8.

Use of a Computer to Simplify Inspection Procedures

Inspecting for all the defects specified in the Army Track Standards is a significant task. Therefore, an important con-
Report Criteria: Condition Comparison by Inspection Type for All Track Segments.

<table>
<thead>
<tr>
<th>TRACK SEGMENT #</th>
<th>NO OPERATION</th>
<th>5 MPH SPEED LIMIT</th>
<th>10 MPH SPEED LIMIT</th>
<th>FULL COMPLIANCE</th>
<th>DEFECT</th>
<th>VEGETATION</th>
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<tr>
<td>1001</td>
<td>TIES</td>
<td>TIES VEGETATION</td>
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<td></td>
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<tr>
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<td>TIES</td>
<td>TIES VEGETATION</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1003</td>
<td>TIES</td>
<td>TIES TURNOUTS T/O GEOM VEGETATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1004</td>
<td>TIES</td>
<td>TURNOUTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1005</td>
<td>TIES</td>
<td>T/O GEOM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1006</td>
<td>TIES</td>
<td>T/O GEOM</td>
<td></td>
<td></td>
<td></td>
<td>VEGETATION</td>
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<tr>
<td>1007</td>
<td>FLNGWAY MEA</td>
<td>TIES TURNOUTS T/O GEOM VEGETATION</td>
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</tr>
<tr>
<td>1008</td>
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<td>VEGETATION</td>
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<tr>
<td>101</td>
<td>TIES</td>
<td>TIES</td>
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<td></td>
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</tr>
</tbody>
</table>

**FIGURE 7** Condition Comparison by Inspection Type report.

<table>
<thead>
<tr>
<th>TRACK SEGMENT #</th>
<th>Maintenance Standard Condition</th>
<th>Total Cost to Raise Condition to Desired Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001</td>
<td>OUT OF SERVICE</td>
<td>$2,002.00</td>
</tr>
<tr>
<td>1002</td>
<td>10 MPH SPEED LIMIT</td>
<td>$1,534.00</td>
</tr>
<tr>
<td>101</td>
<td>OUT OF SERVICE</td>
<td>$1,327.00</td>
</tr>
<tr>
<td>102</td>
<td>OUT OF SERVICE</td>
<td>$3,327.00</td>
</tr>
<tr>
<td>103</td>
<td>10 MPH SPEED LIMIT</td>
<td>$991.00</td>
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<td>701</td>
<td>OUT OF SERVICE</td>
<td>$2,072.00</td>
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<td>5 MPH SPEED LIMIT</td>
<td>$1,469.00</td>
</tr>
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<td>L02</td>
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<td>L03</td>
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<td></td>
<td></td>
<td>$26,288.00</td>
</tr>
</tbody>
</table>

**FIGURE 8** Maintenance and Repair Summary report.
sideration in developing these inspection procedures was easing, as much as possible, the burden of the inspector. This was accomplished in several ways, including, as discussed previously, in the design of the inspection forms.

The RAILER computer software provides another means to this end. The focus on collecting raw data (as discussed previously) is an important example. This is especially true of measurements such as those obtained during turnout inspection (see lower portion of form presented in Figure 3). The inspector does not need to know the acceptable value ranges and the cut-off points for different operating restrictions (severity levels). The inspector only needs to properly make the measurement(s) and enter the values on the form. These values are later compared with the standards, either in the computer or by hand if RAILER is not computer implemented.

The computer software is also designed to prevent the entry of some obviously inconsistent defect combinations such as rail anchors that are pumping (see in Figure 6 Component Code RA and Defect Code PMP). This increases the reliability of the inspection process.

SHORT-LINE APPLICABILITY

Potential technical transfer to the civilian sector is an important consideration in research conducted by the federal government. Early in the development of RAILER, it was observed that many characteristics associated with Army track maintenance management are also true for commercial short lines and industrial networks. These common characteristics include general track quality, service levels and types of operations, and the availability of local expertise.

Therefore, potential use by short lines was a strong consideration throughout the development of RAILER. This was partially accomplished by introducing into RAILER the necessary flexibility to accommodate those areas in which the Army’s needs are not completely consistent with those of potential civilian users. An example of this flexibility is the ability to develop within RAILER customized track standards as discussed previously. The RAILER detailed inspection procedures provide the same benefits for short-line users, as they do for Army users.

FIELD TESTING

The detailed inspection procedures described here have been under development for over 3 years. They have evolved into their present form with the concurrent development of the Army Track Standards. Both involved considerable revision during their history. The development was an iteration process; needed information was ascertained, procedures were then developed to collect the information, these procedures were field tested, and revisions were made. The overall goal was to be able to easily collect the necessary information with trained installation track inspectors.

Many weeks were spent in the field testing the procedures. Teams were sent to the Tooele Army Depot, Utah; Ft Devens, Massachusetts; Ft Stewart, Georgia; and Hunter Army Airfield, Georgia. Additionally, the Urbana, Illinois, yard of the Consolidated Rail Corporation (Conrail) served as a local site.

Generally, data collection procedures were first developed in the laboratory and tested locally. Then, field trips to the installations were scheduled to uncover procedural shortcomings. The various locations were chosen to provide the great variety of operating, climatic, and maintenance differences that were needed to properly test and evaluate the data collection procedures. Also, the field work permitted the researchers to test the practical requirements of the Army Track Standards. Feedback to the developers of the standards resulted in some changes. Those, in turn, resulted in inspection changes and data collection modifications.

The field work has shown that inspection productivity rates are strongly dependent on the condition of the track (i.e., the more defects there are, the longer the inspection takes). The inspections may only progress at a slow walking pace. This is because many of the defects are quite finite and require acute attention to be observed. Also, for the same reason, it was found that it can be nearly impossible for a single inspector to inspect all of the components concurrently. In fact, it may take up to three passes of the track by one inspector to note all of the defects for all of the components. The track can be inspected by one person, but a team of two significantly improves the efficiency; it can be nearly impossible for one person to perform certain manual track geometry inspection tasks.

Based on the range of conditions found at the various installations, one inspector could completely inspect, on foot, approximately 0.3 mi/hr. Turnouts take approximately 15 min each to inspect (time actually spent at the turnout). These are average rates and include allowance for nonproductive walking time (time lost walking back from the end of a terminating track at the completion of an inspection). They do not include travel time to and from the network portion being inspected.

A two-person inspection team was found to be able to inspect at a rate of approximately 0.8 mi/hr. Turnout inspection can be reduced to approximately 8 min.

None of the above productivity rates includes time for manual track geometry measurements.

Track inspection from a moving track vehicle, even at slow speeds (<5 mph), resulted in a number of missed defects.

CONCLUSIONS AND RECOMMENDATIONS

The detailed inspection procedures described in this report were developed for use within the RAILER system. The inspection data collection forms were developed to facilitate relative ease in data collection and recording, as well as eventual loading into installation RAILER data bases for processing and analysis. Testing has shown that this has been accomplished.

These same detailed inspection procedures were designed to satisfy the requirements of the Army Track Standards. The methods and procedures described in this report can be used to satisfy the inspection requirements of those track standards. Also, these inspections are currently intended to satisfy several maintenance management requirements at both the network and project levels ($\ell_1$, $\ell_2$). At the network level, these include identifying safety problems, assessing conditions, developing long-range work plans, budgeting, and prioritizing work for the entire network. Project-level management focuses
on specific track segments and includes quantifying work needs associated with preparing job orders and contracts, determining the cause of the track problems, and selecting the most feasible M&R alternative.

The detailed track inspection procedures are explicitly designed to provide the information required for project-level management, in which detail becomes very important. However, much of that detailed information is not needed for network-level management tasks. Network-level management tasks are performed at least annually, whereas project-level tasks are performed only when and where needed. Thus, most management tasks are at the network level.

The authors believe that management needs should dictate data requirements, not vice versa. Specific information should be collected only when needed to satisfy management needs. Accordingly, simplified track inspection procedures are being formulated as part of the Track Structure Condition Index (TSCI) development currently under way at USA-CERL. The TSCI will measure the “health” of both individual track segments and the overall network. This measure will be the prime tool for network-level management tasks. The new simplified inspection procedures will capture just enough information to perform those tasks, yet at the same time be sensitive enough to identify critical defects requiring immediate attention for safety reasons. The spirit and intent of the Army Track Standards will still be met. A tangible benefit consisting of a significant reduction in inspector hours would result. The detailed inspection procedures described in this report would be reserved for project-level management tasks.

ACKNOWLEDGMENTS

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