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TRACK REHABILITATION AND MAINTENANCE RESEARCH REQUIREMENTS

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FINAL REPORT

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16. Abstract

The Federal Railroad Administration has established a research and development program aimed at improving railroad track safety and performance. As part of the support of that earlier effort, two planning studies were performed which identified track system rehabilitation and maintenance problems, suggested candidate subprograms for solving the problems, and evaluated the subprograms. Subsequently, the two sets of evaluation results were combined to yield a single list of subprograms rank-ordered according to a multi-criterion measure of desirability. This report summarizes the two studies, it describes in summary fashion how two sets of evaluation results were combined, and it presents the combined rank-ordered list of recommended candidate subprograms. These recommended candidate subprograms will be considered by the Federal Railroad Administration, Office of Research and Development as part of the process of establishing track research projects. The selected projects may support a variety of research requirements, in addition to those detailed herein, and therefore may not be implemented precisely as described. Also, the sequence of progression of the projects may not exactly match the recommended rankings due to other considerations which could not be reflected in this report.

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1.0 INTRODUCTION AND SUMMARY

In recent years, the economic health of many of the nation's railroads has declined substantially. Increasing operating expenses and insufficient revenues have driven the average rate of return on net investment from 3.7 percent in 1965 to a low of 1.2 percent in 1975.(1) The low rate of return and other factors such as increased competition, have, in turn, restricted the industry's ability to attract new investment capital. At the same time, the revenue-expense squeeze has also restricted the industry's ability to generate capital internally. Consequently, railroads have had to reduce expenses. Deferring maintenance and fixed-plant improvements have been two approaches used to reduce expenditures. Estimates of industry-wide deferred maintenance expenditures have ranged between $6 billion and $7 billion in 1975.(2)

Logically, the practice of deferring maintenance should have a negative impact on the safety of existing track structure. In fact, train accident statistics do provide one index of track deterioration. For example, derailments have increased an average of 42 percent between 1966 and 1975.(3) Similarly, the number of train accidents in which defects in way or structures were cited as primary contributing factors more than doubled during the same period.(4) A recent Association of American Railroads (AAR) study provides additional evidence.(5) The results of this study suggest that there may be a positive relation between track-related train accidents and deferred maintenance.

Recognizing the importance of high quality track to the safety and financial viability of the overall railroad industry, both Congress and the Federal Railroad Administration (FRA) have taken action. In 1976, Congress passed the Railroad Revitalization and Regulatory Reform Act (4R Act) which, among other things, provides capital to the railroads for rehabilitation and maintenance of facilities including track structures. FRA, on the other hand, has incorporated an Improved Track Structures Research program into its overall research and development (R&D) activity. The program's objective is a safer and more cost-effective track system.

An existing portion of the Improved Track Structures Research Program addresses the objectives of achieving improved safety. This report addresses the second portion of the program--the cost effective performance of the track system as affected by maintenance and rehabilitation.

1.1 Study Objective and Scope

As with many major R&D efforts, the resources of the Improved Track Structures Research Program are not sufficient to address all problems associated with track systems. Furthermore, solutions to some problems are more important than solutions to others, and the cost in R&D dollars will be more for some solutions and less for others. This leads to an important question. How should the limited resources of this program be allocated to the problems?

To help answer this question, FRA contracted for two studies: one with The MITRE Corporation, the other with the firm of Parsons, Brinckerhoff, Quade and Douglas, Incorporated (PBQ&D). The studies sought to identify alternative R&D areas or thrusts aimed at improving the cost effective performance of the track system, and to rank-order those alternatives according to some measure, or set of measures, which reflects both government and industry concerns.

Although the studies have a common objective, they have different constraints. The MITRE study dealt primarily with track rehabilitation oriented R&D, while the PBQ&D study dealt primarily with track maintenance oriented R&D--with full recognition that the line dividing the two is not always clear. Furthermore, the MITRE study based its findings on information obtained from the literature, from representatives of government and the research community, and from railroads owned by the federal government or engaged in extensive rehabilitation efforts with federal financial aid.(6) The PBQ&D study, on the other hand, based its findings on results obtained from the literature, from other railroads, from the railroad supply industry, and from the trade press.(7) Results of both studies will be used by FRA to complete the definition of the Improved Track Structures Research Program.

1.2 Report Objective

As indicated earlier, each study identified and rank-ordered a set of alternative R&D thrusts or efforts. To facilitate use, the results of both studies were combined into a single rank-ordered list of R&D alternatives. This report describes how the results were combined, and it presents the single rank-ordered list. It also describes, in summary fashion, the methods used in the two studies and the resulting alternatives.

1.3 Some Definitions

In describing the two studies and their results, it will be convenient to use three terms--project, subprogram and program--which frequently mean different things to different people. To avoid misunderstanding, the terms are defined here.

A project is defined as a unit of work, typically subdivided into tasks, performed under a single contract or order, contained within a single subprogram, and having an explicitly stated cost, a stated duration, and an objective. A subprogram is defined as a series of projects, or a single project, which delineates a specific approach toward solving a specific problem and is directed toward a quantifiable objective which can be either a product or a finding of value to the government or to the railroad industry. Earlier, the term "solution approach" and the phrase "alternative R&D areas or thrusts" were used to describe what will hereafter be referred to as a subprogram. A program (e.g., the Improved Track Structures Research Program) is composed of one or more subprograms.

2.0 METHODS

In general, the approach followed in both studies consisted of three steps.

- problem identification and ranking
- subprogram definition
- subprogram evaluation

The manner in which these steps were taken, however, was somewhat different--particularly in the cases of the second and third steps. Brief descriptions of each contractor's approach to these steps are presented here. The section concludes with a description of the process by which the two sets of subprograms were rank-ordered as a single set.

To help assure that the methods would lead to meaningful results, a Technical Review Panel was established by FRA to review and comment on the two studies as they progressed. The panel, composed of railroad, railroad supply industry, and government representatives met seven times and, separately, critically reviewed this report. Panel members are listed in Appendix C.

2.1 Problem Identification and Ranking

2.1.1 MITRE Approach

Initially, a preliminary list of track system problems was compiled based on information obtained from the MITRE staff, the literature, and from a survey conducted by the Association of American Railroads (AAR) several years earlier.(8) The problems were then classified by track system component and according to whether they concerned inadequate materials, inadequate methods, or insufficient information about existing materials or methods. The classified list served as a basis for discussing track system problems with a number of knowledgeable people.

In all, 52 people were interviewed. Eighteen represented three government organizations, 22 represented 15 R&D contractors, nine represented three railroads, and three represented the Association of American Railroads. Each interviewee was asked to do the following:

1. Review the list of track system problems.
2. Add any new problems to the list which were believed to be at least as important as those on the list.
3. Identify the more important problems on the list.
4. Rank-order the more important problems.

Of the 52 interviewees, 42 provided sufficient problem ranking information to allow their results to be combined with that of others into a composite ranking. The remainder felt unqualified to rank outside their area of expertise (e.g., ballast or subgrade), or unqualified to rank at all.

In all, 66 different problems were identified and rank-ordered. They are shown in Appendix A. The scores upon which the rank-ordering is based were developed by combining each interviewee's rank-ordering of his set of important problems. Details of the procedure are in the MITRE report.(6)

2.1.2 PBQ&D Approach

Initially, a list of problems similar to that used by MITRE was assembled. It too served as a basis for discussion during interviews with representatives of 23 Class I railroads, three trade journals, five material suppliers and four equipment manufacturers.

The information obtained from the interviews varied somewhat in format because the discussion was not formally structured nor was a formal questionnaire used. The interviewers strived to let the interviewees talk freely about their track problems without prompting or asking leading questions. As in the MITRE effort the interviewees were asked to rank-order the problems they deemed most important. Some did and some did not. When they did not, the interviewers did the ranking by considering the length of discussion time devoted to a particular problem and by using judgment. The individual rank-orderings were then combined by the PBQ&D staff to develop a rank-ordered list of all problems.

In all, 78 different track system problems were identified and rank-ordered. They are shown in Appendix A.

2.2 Subprogram Definition

2.2.1 MITRE Approach

Given the rank-ordered list of track system problems, the highest ranking track rehabilitation--rather than track maintenance--problem was selected and a corresponding subprogram was defined. The information required to describe the subprogram was obtained from four sources: the interviews described earlier, literature reviews, telephone conversations with the interviewees and other experts, and the experience of the study team. Typically, a subprogram designed to solve one problem actually affected several problems due to the particular solution approach developed. For example, solving the problems of excessive rail wear through improved rail metallurgy also goes a long way toward solving the problems of premature rail failure and excessive rail corrugation.

After the highest ranking problem was addressed, the next highest ranking problem without a corresponding subprogram was selected and a subprogram was defined. This process was repeated until the study resources allocated to the subprogram definition task were depleted. In all, 13 subprograms were defined. They are listed in Table I. Summary descriptions of each subprogram are provided in Appendix B.

Table II shows how the subprograms relate to the 30 highest ranking problems. In all, 18 problems are attacked directly by the 13 subprograms, while an additional eight problems are attacked indirectly.

TABLE I

TRACK REHABILITATION R&D SUBPROGRAMS--MITRE STUDY

ID	Title
A	Track System Handbook
B	Improved Lateral Track Stability
C	Improved Rail Metallurgy
D	In-Place Rail Hardening
E	Improved Thermite Welding
F	On-Site Electric Flash-Butt Welding
G	In-Place Rail Welding
H	Bolt Hole Crack Prevention
I	In-Place Bolt Hole Crack Restraint
J	Improved Wood Tie Fastening System
K	Improved Wood-Based Tie
L	In-Place Repair of Spike-Killed Ties
M	Improved Concrete Tie and Fastener Selection and Utilization

2.2.2 PBQ&D Approach

Since the MITRE study preceded the PBQ&D study by several months, the MITRE study had already developed subprograms that addressed many of the problems uncovered in the PBQ&D study. These problems were not considered by PBQ&D when developing their subprograms. The revised list was presented to the Technical Review Panel and each panel member was asked to select nine that he considered most important. Using the panel members views and the direct results

TABLE II

PROBLEMS VERSUS SUBPROGRAMS--MITRE STUDY

RANK	PROBLEM DESCRIPTION	A	B	C	D	E	F	G	H	I	J	K	L	M
1.	INADEQUATE TRACK STRUCTURE COST/PERFORMANCE DATA	●												
2.	EXCESSIVE RAIL WEAR	o		●	●									
3.	INSUFFICIENT COST/PERFORMANCE INFORMATION ON BALLAST	●												
4.	EXCESSIVE LONGITUDINAL RAIL STRESS	o	●											
5.	INADEQUATE CONCRETE TIE PERFORMANCE													o
6.	INADEQUATE MAINTENANCE OF WAY METHODS													
7.	INADEQUATE PERFORMANCE OF SPIKES/PLATES AS FASTENERS										●			
8.	INSUFFICIENT COST/PERFORMANCE DATA--PROPER RAIL SELECTION	●		o										
9.	PREMATURE RAIL FAILURE			●	●									
10.	INSUFFICIENT INFORMATION ABOUT SUBGRADE PERFORMANCE	●												
11.	INADEQUATE FIELD WELDING TECHNIQUES					●	●	●						
12.	UNKNOWN COST/PERFORMANCE OF SUBGRADE IMPROVEMENT METHODS	●												
13.	EXCESSIVE RAIL PLASTIC FLOW DEFECTS			●	●									
14.	INADEQUATE CONCRETE TIE FASTENER DESIGN													o
15.	INADEQUATE METHODS FOR SUBGRADE IMPROVEMENT	o												
16.	EXCESSIVE BALLAST DEGRADATION	o												
17.	EXCESSIVE BALLAST/SUBGRADE INTERACTIONS (PUMPING)	o												
18.	TRACK SYSTEM R&D RESULTS NOT PROPERLY DISSEMINATED	o	o	o	o	o	o	o	o	o	o	o	o	o
19.	EXCESSIVE WOOD TIE DEGRADATION	o									o	●	●	
20.	BOLT/BOLT HOLE PROBLEMS			o	o				●	●				
21.	INADEQUATE WOOD TIE RENEWAL/DISPOSAL METHODS	o												
22.	HIGH CONCRETE TIE INITIAL/INSTALLATION COSTS											o	o	
23.	INABILITY TO DETERMINE RAIL STRESSES IN THE FIELD		●											
24.	UNKNOWN ANCHOR EFFECTIVENESS/PERFORMANCE	●	o											
25.	INADEQUATE FIELD RAIL FLAW DETECTION													
26.	UNKNOWN FUTURE COST/AVAILABILITY OF WOOD TIES											●		
27.	INSUFFICIENT COST/PERFORMANCE DATA--OPTIMUM WOOD TIE UTILIZATION	●												
28.	INSUFFICIENT KNOWLEDGE ABOUT COST/PERFORMANCE OF SPECIAL TRACKWORK													
29.	INADEQUATE FROG MAINTENANCE METHODS													
30.	TRACK GEOMETRY PROBLEMS	o												

Note: ● = primary relationship
o = secondary relationship

of PBQ&D interviews, FRA staff selected seven subprograms for defintion and evaluation. The subprograms are listed in Table III and described briefly in Appendix B. Table IV shows how the subprograms relate to the high ranking problems.

TABLE III

TRACK AND BRIDGE MAINTENANCE R&D SUBPROGRAMS--PBQ&D STUDY

ID	TITLE
N	Bridge Inspection, Rating and Evaluation of Remaining Life
O	Subgrade Stabilization and Improvement
P	Timber Cross Tie Rehabilitation and Disposal
Q	Special Trackwork Maintenance
R	Bolted Joints
S	Ballast Fouling from External Sources
T	Switch Point Wear Limits

2.3 Subprogram Evaluation

At this point the 13 MITRE and seven PBQ&D subprograms were considered to be of equal value or worth. The fact that some addressed higher ranking problems than others was no longer relevant since the subprogram evaluation and ranking processes would distinguish between subprograms and help establish priorities.

The subprogram evaluation approach adopted for both studies was primarily quantitative rather than qualitative. The quantitative portion of the work was based on objective analyses performed by the respective study staffs, while the qualitative portion was based on the subjective judgment of two groups of evaluators convened solely for the purpose of evaluating the subprograms. The evaluators were selected jointly by the study staffs and FRA.

TABLE IV

PROBLEMS VERSUS SUBPROGRAMS--PBQ&D STUDY

PROBLEM RANK	PROBLEM DESCRIPTION	SUBPROGRAM N	O	P	Q	R	S	T	MITRE
1.	INADEQUATE PERFORMANCE OF SPIKES/PLATES AS FASTENERS*								●
2.	EXCESSIVE RAIL WEAR								●
3.	INADEQUATE TECHNIQUE FOR EVALUATING REMAINING BRIDGE LIFE	●							
4.	INSUFFICIENT COST/PERFORMANCE INFORMATION ON BALLAST								●
5.	INADEQUATE WOOD TIE RENEWAL/DISPOSAL METHODS			●					
6.	EXCESSIVE RAIL PLASTIC FLOW DEFECTS								●
7.	INABILITY TO DETERMINE RAIL STRESSES IN THE FIELDS								●
8.	UNKNOWN COST/PERFORMANCE OF SUBGRADE IMPROVEMENT METHODS		●						
9.	INADEQUATE METHODS FOR SUBGRADE IMPROVEMENT		●						
10.	PREMATURE RAIL FAILURE								●
11.	INADEQUATE TRACK GEOMETRY MEASURING METHODS*								
12.	INADEQUATE FIELD RAIL FLAW DETECTION*								
13.	INADEQUATE TRACK STRUCTURE COST/PERFORMANCE DATA								●
14.	EXCESSIVE LONGITUDINAL RAIL STRESS								●
15.	EXCESSIVE BALLAST/SUBGRADE INTERACTIONS (PUMPING)		●						
16.	INADEQUATE BRIDGE REPAIR/MAINTENANCE TECHNIQUES	●							
17.	INADEQUATE METHOD OF WATERPROOFING BRIDGE DECKS								
18.	INADEQUATE FIELD WELDING TECHNIQUES								●
19.	EXCESSIVE SWITCH WEAR				●			●	
20.	INADEQUATE MAINTENANCE OF WAY METHODS		o	o	o	o	o	o	
21.	EXCESSIVE WOOD TIE DEGRADATION								
22.	UNKNOWN ANCHOR EFFECTIVENESS/PERFORMANCE								
23.	INADEQUATE METHOD OF DETECTING FATIGUE CRACKS IN STEEL BRIDGES	●							
24.	INADEQUATE BOLTED INSULATED JOINT PERFORMANCE					●			
25.	INADEQUATE METHODS OF TUNNEL DRAINAGE								
26.	EXCESSIVE FROG WEAR AND FAILURE RATE				●				
27.	UNKNOWN FUTURE COST/AVAILABILITY OF WOOD TIES								●
28.	UNKNOWN LIMITS OF SWITCH POINT WEAR AND CONDITION							●	
29.	INADEQUATE BRIDGE RATING PROCEDURES	●							
30.	DEFICIENCIES IN BRIDGE INSPECTION METHODS/TOOLS	●							
31.	EXCESSIVE BALLAST FOULING						●		

Note: ● = primary relationship
o = secondary relationship
* = adequately covered under existing FRA efforts

The cornerstone of the method was the set of criteria against which the subprograms were evaluated. The criteria, described briefly in Table V, reflect multiple objectives. They consider the Improved Track Structures Research program objectives of safer and more cost-effective track; they reflect the need to maximize the return on FRA's limited R&D budget; and they account for benefits accruing to the railroads which might not be readily quantifiable.

In any evaluation process with multiple evaluators and multiple criteria, it is likely that there will be disagreement among the evaluators concerning the relative importance of each criterion.

TABLE V

SUBPROGRAM EVALUATION CRITERIA

Criterion	Description
Benefit-Cost Ratio	Present value of net dollar benefit to RR industry divided by R&D cost
Safety Impact	Number of accidents prevented in first 5 years of implementation
Capital Savings	Capital expenditures saved in first 5 years of implementation
Timeliness	R&D time in years
Other Impacts	Subjectively selected value from a scale of -5 to +5
R&D Cost	Total subprogram R&D cost

Rather than force the evaluators to agree, six weighting (or importance) factors were incorporated into the process--one weighting factor for each criterion. Each evaluator subjectively and independently determined values for the six weighting factors, and each measure was then normalized and multiplied by its corresponding weighting factor. Once an evaluator determined his set of weighting factors, those values were used in his evaluation of each subprogram.

Implicit in the nature of R&D activities is an element of risk--some efforts fail, others succeed. In effect, the probability of success varies from effort to effort. There is a chance, therefore, that the benefits envisioned from a subprogram might not be achieved. To take this into account, each evaluator was asked to subjectively estimate the probability of success of each subprogram.

For each subprogram, and each evaluator, the criterion measurement values, the weighting factors and the risk or probability of success factor were linearly combined to yield a single subprogram score. The score became the basis for rank-ordering the subprogram for each evaluator. It is worth noting that the probability of success factor, or risk, played an important role in determining a subprogram's score. It was a multiplier of all the evaluation measures indicative of benefit (i.e., all but R&D Cost). Since its value was almost always less than one, it reduced the expected benefit--sometimes substantially if the probability of success was judged to be low.

The sum of each subprogram's score across all evaluators was used as a basis for obtaining an overall, or group, rank-ordering.

2.3.1 MITRE Approach

For each of the 13 subprograms defined in the study, values for the five objective measures shown in Table V (all except "Other Impacts) were estimated by the MITRE staff. The 13 "Other Impact" values, the six weighting factors, and the 13 probability of success factors were subjectively estimated by 20 evaluators. The evaluators included the TRP members, some of the individual's interviewed earlier in the study, FRA staff, study team staff, and several others experienced in track system R&D.

Results of the above efforts are summarized in Tables VI and VII. It should be noted that the "Other Impact" values, the probability of success factors and the weighting factors shown there are the averages of the 20 estimates provided by the evaluators. As such they were not actually used in the rank-ordering process; rather the individual estimates were used. The averages are presented here only as an indicator of the position of the group as a whole.

TABLE VI

AVERAGES OF EVALUATOR ESTIMATES OF CRITERIA WEIGHTING FACTORS

Factor	Weight
Benefit-Cost Ratio	0.40
Safety Impact	0.15
Capital Savings	0.16
Timeliness	0.12
Other Impacts	0.09
R&D Cost	0.07

TABLE VII

VALUES OF SUBPROGRAM EVALUATION MEASURES--MITRE STUDY

Subprogram	Benefits ($'s In Millions)	R&D Costs ($'s In Millions)	Benefit-Cost Ratio	Safety Impact (Accidents Prevented)	Capital Savings ($'s In Millions)	R&D Time (Years)	Other Impacts	Prob. Of Success
A	261.4	$5.70	45.9	252	144.0	7.0	1.85	0.67
B	49.4	1.30	37.9	114	11.3	3.8	1.45	0.46
C	1.8	1.40	1.3	1	- 3.0	6.2	1.61	0.51
D	533.8	1.60	340.0	83	-37.8	4.5	0.71	0.31
E	1.3	0.50	2.6	6	0.2	3.7	0.90	0.54
F	20.6	0.32	65.4	6	10.6	2.2	0.41	0.60
G	422.1	0.62	680.8	0	232.5	3.9	0.31	0.22
H	3.5	0.13	26.9	7	- 1.6	4.8	0.73	0.66
I	6.0	0.71	8.4	0	3.3	3.7	0.29	0.42
J	6.7	1.70	3.9	2	- 4.8	6.0	0.96	0.42
K	3.2	0.89	3.6	0	- 4.7	4.3	1.21	0.44
L	320.4	0.41	781.5	0	321.9	3.7	0.80	0.55
M	9.5	1.90	5.0	0	- 9.3	6.1	0.86	0.52

2.3.2 PBQ&D Approach

As in the MITRE study, values for the five objective measures were estimated by the PBQ&D staff for each of the seven PBQ&D subprograms. The subjective estimates, however, were developed differently than in the MITRE study.

Ideally, the subjective estimates should have been provided by the same 20 evaluators used in the MITRE study. Since the PBQ&D study followed the MITRE study by several months, a second conference, with its attendent expense to the unreimbursed evaluators, would have been necessary. To avoid this, a group of seven evaluators, two from the PBQ&D staff, two from the MITRE staff, and three from FRA, convened for one day and each evaluator developed estimates for the "Other Impact" values and the probability of success factors. The eight estimates for each parameter were averaged to yield a single estimate for each of the seven values and seven factors. These were then assumed to be the estimates that the 20 evaluators in the MITRE study would have provided had the PBQ&D subprograms been available at the MITRE evaluation conference.

Results of the above effort are shown in Table VIII. Here again the "Other Impact" values and the probability of success factors are the averages of the seven estimates provided by the evaluators.

TABLE VIII

VALUES OF SUBPROGRAM EVALUATION MEASURES--PBQ&D STUDY

Subprogram	Benefits ($'s In Millions)	R&D Cost ($'s In Millions)	Benefit-Cost Ratio	Safety Impact (Accidents Prevented)	Capital Savings ($ In Millions)	R&D Time (Years)	Other Impacts	Prob. Of Success
N	113.0	4.1	28.0	0	62.5	3.0	2.10	0.54
O	178.0	4.5	40.0	96	53.4	4.0	2.30	0.45
P	208.0	2.1	99.0	0	115.0	3.0	0.10	0.34
Q	186.0	3.4	55.0	137	81.0	6.0	2.10	0.47
R	328.0	2.2	149.0	75	120.0	3.0	1.00	0.45
S	107.0	1.4	76.0	141	22.4	3.0	0.30	0.19
T	300.0	1.4	214.0	572	-79.0	5.0	2.10	0.43

3.0 RESULTS

Application of the subprogram evaluation method described earlier to the 20 subprograms developed by MITRE and PBQ&D produced the rank-ordered list shown in Table IX. It should be remembered that the evaluation score is the sole basis for that rank-ordering. As a practical matter, other qualitative considerations such as barriers to implementation or logical relationships between subprograms will dictate the final priority or rank of each subprogram. Such considerations, plus the inherent uncertainty in both the data and method, suggest that the true rank or priority at this point is also uncertain by at least several ranking levels.

With the above considerations aside, Table IX indicates the most desirable R&D effort to be In-Place Repair of Spike-Killed Ties. Briefly, this is a well designed experiment aimed at conclusively determining the cost and the capability of the much heralded resin spike hole filler for extending the service life of spike-killed ties. This is, to be sure, not a complex R&D effort. It is, however, one worthy of a conclusive test. For if the manufacturer's claims are verified, the benefits are apt to be quite large.

The next highest ranking effort is the Switch Point Wear Limits subprogram. It seeks improved methods for inspecting and maintaining switch points as well as better information about performance, cost, and benefit of "improved" special trackwork components. The accident reduction potential and the monetary benefit appear to be quite large.

At the third priority level are two subprograms concerned with rail joining. One seeks to develop a method of welding rails in-place without removal of the tie-rail fastening system at a cost and quality comparable to in-plant welds. Several welding techniques

TABLE IX

IMPROVED TRACK STRUCTURE RESEARCH SUBPROGRAMS--RANK-ORDERED

Rank	Score	Subprogram
1	146	In-Place Repair of Spike-Killed Ties
2	71	Switchpoint Wear Limits
3	60	In-Place Rail Welding
4	60	Bolted Joints
5	56	On-Site Electric Flash-Butt Welding
6	52	Bolt Hole Crack Prevention
7	52	Track System Handbook
8	48	Improved Lateral Track Stability
9	48	Bridge Inspection, Rating and Evaluation of Remaining Life
10	46	Improved Thermite Welding
11	45	In-Place Rail Hardening
12	42	Special Trackwork Maintenance
13	41	Timber Cross-Tie Rehabilitation and Disposal
14	40	Subgrade Stabilization and Improvement
15	36	Improved Wood-Based Tie
16	36	In-Place Bolt Hole Crack Restraint
17	32	Improved Rail Metallurgy
18	31	Ballast Fouling from External Sources
19	30	Improved Wood Tie Fastening System
20	28	Improved Concrete Tie and Fastener Selection and Utilization

which have not been tested under such circumstances are candidates. If such a technique could be developed it could be used to replace virtually all bolted joints with welded joints.

The other effort at the third priority level seeks better designs and maintenance methods for bolted joints. Here the monetary benefit, short term capital savings and accident reduction potential are all large.

In a sense, the two third priority level subprograms have the same objective--substantial reduction of the many problems associated with bolted joints. With a limited R&D budget and a host of other track system problems and potential solution approaches, they should not be undertaken simultaneously. A small amount of additional study by FRA staff, would be sufficient to decide which should be pursued first.

Summary descriptions of the lesser ranked subprograms are in Appendix B and estimates of their beneficial aspects are shown in Tables VII and VIII.

A word of caution, however, is in order prior to implementing any subprogram. First, there is uncertainty in the data used to estimate subprogram benefits. Although the data are believed to be sufficiently accurate to allow ranking of one subprogram relative to another, the data, in all likelihood are not sufficiently accurate to allow quoting an absolute benefit or benefit-cost ratio of a particular subprogram in isolation from values for other subprograms without a long list of qualifications about the data involved. Second, the cost data used in this study are based on 1978 dollars and must be adjusted for inflation rates of future time periods. Finally, individual subprogram benefits cannot be arithmetically summed to obtain maximum achievable benefits; to do so would be to overstate benefit expectations.

APPENDIX A

RANK-ORDERED TRACK SYSTEM PROBLEMS

TABLE X

RANK-ORDERED TRACK SYSTEM PROBLEMS--MITRE STUDY

Rank	Problems	Score
1.	Inadequate Track Structure Cost/Performance Data	1039.0
2.	Excessive Rail Wear	200.7
3.	Insufficient Cost/Performance Information on Ballast	197.5
4.	Excessive Longitudinal Rail Stress	189.4
5.	Inadequate Concrete Tie Performance	172.3
6.	Inadequate Maintenace of Way Methods	161.1
7	Inadequate Performance of Spikes/Plates as Fasteners	151.5
8.	Insufficient Cost/Performance Data--Proper Rail Selection	146.9
9.	Premature Rail Failure	146.3
10.	Insufficient Information about Subgrade Performance	122.1
11.	Inadequate Field Welding Techniques	118.3
12.	Unknown Cost/Performance of Subgrade Improvement Methods	108.8
13.	Excessive Rail Plastic Flow Defects	97.3
14.	Inadequate Concrete Tie Fastener Design	89.9
15.	Inadequate Methods for Subgrade Improvement	83.9
16.	Excessive Ballast Degradation	81.6
17.	Excessive Ballast/Subgrade Interactions (Pumping)	81.0
18.	Track System R&D Results Not Properly Disseminated	79.8
19.	Excessive Wood Tie Degradation	77.8
20.	Bolt/Bolt Hole Problems	75.5
21.	Inadequate Wood Tie Renewal Methods	69.8
22.	High Concrete Tie Initial Installation Costs	67.6
23.	Inability to Determine Rail Stresses in the Field	62.0
24.	Unknown Anchor Effectiveness/Performance	60.9
25.	Inadequate Field Rail Flaw Detection	60.5
26.	Unknown Future Cost/Availability of Wood Ties	55.4
27.	Insufficient Cost/Performance Data--Optimum Wood Tie Utilization	54.1
28.	Insufficient Knowledge about Cost/Performance of Special Trackwork	53.8
29.	Inadequate Frog Maintenance Methods	53.2
30.	Track Geometry Problems	46.5
31.	Insufficient Information--Cost/Performance of Innovative Wood-Base Ties	44.2
32.	Excessive Switch Wear	44.2
33.	Insufficient Cost/Performance Data--Innovative Wood Tie Fasteners	37.4
34.	Inadequate Subgrade Assessment Techniques	36.5
35.	Insufficient Cost/Performance Data--Wood Tie Selection	35.9
36.	Inadequate Concrete Tie Cost/Performance Data	34.7
37.	Excessive Ballast Fouling	33.0

TABLE X (CONCLUDED)

RANK-ORDERED TRACK SYSTEM PROBLEMS--MITRE STUDY

Rank	Problems	Score
38.	Inadequate Slope Stabilization Methods	29.6
39.	Insufficient Information on the Causes of Railway Accidents	27.5
40.	Inadequate Stock Rail Maintenance Methods	26.0
41.	Inadequate Ballast Maintenance/Rehabilitation Methods	25.3
42.	Inadequate MOW Methods at Crossings	24.7
43.	Inadequate Joint Maintenance Methods	24.6
44.	Cost/Benefits Associated with Tie Plate Area Unknown	23.0
45.	Subgrade Heaving	21.9
46.	Inadquate MOW Methods at Switches	19.5
47.	Inadequate Methods for Evaluating In-Situ Track	17.9
48.	Unknown Cost/Performance	17.4
49.	Inadequate Bonded Joint Maintenance	17.3
50.	Inadequate Field Weld Inspection Techniques	16.6
51.	Track System R&D Goals Not Clear--Gov/Public/RR Conflicts	15.6
52.	Premature Joint Bar Breakage	15.1
53.	Unknown Effects of Track Design/Irregularities on Rail Vehicles	14.3
54.	High Cost of Insulated Joint Installation Methods	13.4
55.	Inadequate Cost/Perf Data--Optimum Joint Bar for Conditions	12.7
56.	Inadequate Anchor Installation Methods	12.7
57.	Line Speed/Yard Capability Not Compatible	12.6
58.	Inadequate Field Joint Bar Flaw Detection	11.1
59.	Excessive Joint Bar Wear	10.6
60.	Inadequate Vegetation Control Methods	9.5
61.	Inadequate Methods for Maintaining Track Geometry at Spec Trackwork	8.6
62.	Inadequate Bolted Insulated Joint Performance	7.1
63.	Inadequate Bonded Joint Performance	5.7
64.	Too Much Curved Track (Line Modification Needed)	3.8
65.	Insufficient Information about Non-Conventional Structures	3.2
66.	Unrealistic Government Track Standards Regulatory Action	2.1

TABLE XI

RANK-ORDERED TRACK SYSTEM PROBLEM--PBQ&D STUDY

Rank	Problem	Score
1.	Inadequate Performance of Spikes/Plates as Fasteners	366.9
2.	Excessive Rail Wear	290.4
3.	Inadequate Technique for Evaluating Remaining Bridge Life	244.6
4.	Insufficient Cost/Performance Information on Ballast	221.7
5.	Inadequate Wood Tie Renewal/Disposal Methods	214.0
6.	Excessive Rail Plastic Flow Defects	191.1
7.	Inability to Determine Rail Stresses in the Field	168.2
8.	Unknown Cost/Performance of Subgrade Improvement Methods	168.2
9.	Inadequate Methods for Subgrade Improvement	168.2
10.	Premature Rail Failure	142.9
11.	Inadequate Track Geometry Measuring Methods	137.6
12.	Inadequate Field Rail Flaw Detection	129.9
13.	Inadequate Track Structure Cost/Performance Data	107.0
14.	Excessive Longitudinal Rail Stress	99.4
15.	Excessive Ballast/Subgrade Interactions (Pumping)	99.4
16.	Inadequate Bridge Repair/Maintenance Techniques	91.7
17.	Inadequate Method of Waterproofing Bridge Decks	91.7
18.	Inadequate Field Welding Techniques	84.1
19.	Excessive Switch Wear	84.1
20.	Inadequate Maintenance of Way Methods	84.1
21.	Excessive Wood Tie Degradation	84.1
22.	Unknown Anchor Effectiveness/Performance	76.4
23.	Inadequate Method of Detecting Fatigue Cracks in Steel Bridges	76.4
24.	Inadequate Bolted Insulated Joint Performance	68.8
25.	Inadequate Methods of Tunnel Drainage	68.8
26.	Excessive Frog Wear and Failure Rate	61.1
27.	Unknown Future Cost/Availability of Wood Ties	53.5
28.	Unknown Limits of Switch Point Wear and Condition	53.5
29.	Inadequate Bridge Rating Procedures	53.5
30.	Deficiencies in Bridge Inspection Methods/Tools	53.5
31.	Excessive Ballast Fouling	49.7
32.	Inadequate Subgrade Assessment Techniques	45.9
33.	Insufficient Track Availability for Maintenance	45.9
34.	Inadequate Concrete Tie Fastener Design	45.9
35.	Track System R&D Results Not Properly Disseminated	38.2
36.	Insufficient Cost/Performance Data-Optimum Rail Length	30.6
37.	Non-Standardization of Track Components	30.6
38.	Excessive Ballast Degradation	26.8
39.	Excessive Eye-Bar Wear in Bridges	22.9
40.	Inadequate Bridge Expansion Bearing Performance	22.9

TABLE XI (CONTINUED)

RANK-ORDERED TRACK SYSTEM PROBLEM--PBQ&D STUDY

Rank	Problem	Score
41.	Inadequte Performance of Bridge Expansion Joints	22.9
42.	Excessive Concrete Spalling on Bridges	22.9
43.	Bolt/Bolt Hole Problems	22.9
44.	Inadequate Joint Maintenance Methods	22.9
45.	Inadequate Joint Performance at Turnouts	22.9
46.	Insufficient Cost/Performance Data--Innovative Wood Tie Fasteners	22.9
47.	Inadequate Timber Tie Installation Methods	22.9
48.	High Concrete Tie Initial/Installation Methods	22.9
49.	Inadequate Concrete Tie Cost/Performance Data	22.9
50.	Inadequate MOW Methods at Crossings	22.9
51.	Inadequate Tunnel Inspection Methods/Tools	22.9
52.	Insufficient Cost/Performance Data--Proper Rail Selection	15.3
53.	Inadequate Rail Lubrication Methods	15.3
54.	Premature Joint Bar Breakage	15.3
55.	Insufficient Information about Subgrade Performance	15.3
56.	Inadequate Slope Stabilization Methods	15.3
57.	Insufficient Cost/Performance Data--Optimum Wood Tie Utilization	15.3
58.	Inadequate Wood Tie Cost/Performance Data	15.3
59.	Inadquate Protection from Blowing Soil	15.3
60.	Inadequate Methods of Preserving Wood Decks on Bridges	15.3
61.	Insufficient Knowledge of CWR Behavior on Bridges	15.3
62.	Inadequate Techniques for Specific Tunnel Repairs	15.3
63.	Inadequate Bridge Pier Protection Methods	7.6
64.	Inadequate Methods of Protection of Bridge Concrete Surfaces	7.6
65.	Inadequate Methods for Fireproofing Bridge Decks	7.6
66.	Inadequate Fire Protection for Timber Tunnels	7.6
67.	Insufficient Information--Cost/Performance of Innovative Wood-Base Ties	7.6
68.	Snow and Ice in Switch Points	7.6
69.	Excessive Track Damage from Anchors Due to Derailments	7.6
70.	Damage to Bridges from Loose Loads	7.6
71.	Insufficient Information about PSC Bridge Spans	7.6
72.	Insufficient Cost/Performance Date on Bridge Steel Protective Coating	7.6
73.	Excessive Spalling of Tunnel Rock or Concrete Lining	7.6
74.	Inadequate Tunnel Track Maintenance Methods	7.6
75.	Insufficient Knowledge about Cost/Performance of Special Trackwork	2.3

TABLE XI (CONCLUDED)

RANK-ORDERED TRACK SYSTEM PROBLEM--PBQ&D STUDY

Rank	Problem	Score
76.	Inadequate Stock Rail Maintenance Methods	2.3
77.	Inadequate MOW Methods at Switches	2.3
78.	Inadequate Methods for Maintaining Track Geometry at Special Trackwork	2.3

APPENDIX B

SUBPROGRAM SUMMARY DESCRIPTIONS

B.0 SUBPROGRAM SUMMARY DESCRIPTIONS

In this Appendix each of the 13 MITRE and seven PBQ&D subprograms are summarized. Brief information is presented relative to the problem to be solved, the R&D objective to be attained, the present level of understanding about each problem, the R&D projects required, and the estimated R&D costs and time to complete the subprogram. It is important to keep in mind that both R&D costs and schedules are estimates which must be periodically monitored and updated as more information on each R&D project becomes available. The order in which the subprograms are discussed reflects their association with rank-ordered problems before the application of the evaluation process.

Considerably more detailed subprogram descriptions are in the MITRE and PBQ&D study reports.(6,7)

B.1 MITRE Subprograms

B.1.1 Subprogram A--Track System Handbook

Problem--Railroad engineering, track maintenance, and government personnel administering financial support programs recognize the need for cost-effective track structures. They do not, however, have the cost and performance information necessary to design such structures, to evaluate such structures when they are proposed, or to recommend proper maintenance or rehabilitation practices for existing structures.

Objective--Develop a track system handbook which will help railroads determine optimal or near optimal track structures, as well as maintenance and rehabilitation practices, for various loading, environmental and subgrade conditions such that total annual track construction, rehabilitation and maintenance expenditures are reduced by 1.2 percent relative to their cost without the handbook.

State-of-the-Art--The literature contains a variety of isolated information and mathematical relationships concerning the track system and its components. Some are old, some are new. Several researchers claim this information can be integrated into a track structure model capable of producing the information needed in the handbook. One claims to possess such a model. Others believe that considerably more work in the form of component degradation and maintenance cost and effectiveness model development must be done.

R&D Projects Required--This subprogram is composed of 12 distinct R&D projects which are briefly described below.

1. Requirements Study--specifies the information potential users of the Handbook will need in order to use the Handbook and identifies information readily available.

2. Track System Handbook-Version I--satisfies all or a reasonable subset of initial requirements determined in Project 1 and is developed using existing models with minimal additional data collection efforts.

3. Results Dissemination and Evaluation-Version I--conduct a seminar for those who make or influence track system decisions in order to get the contents of the Handbook to users as quickly as possible.

4. Feasibility Conference-Version II--convene a workshop with track system modeling and research experts to determine the technical and commercial feasibility of developing a better version of the Handbook.

5. Macro-Level Model Design--design a track system model which, when properly calibrated and validated, will be capable of generating information required in the Handbook.

6. Component and Geometry Degradation Studies--includes six projects directed at developing mathematical models of track component (e.g., rail, tie, fastener...) and track geometry degradation as a function of service.

7. Component and Geometry Restoration and Cost Studies--includes three projects designed to predict the cost and operational restoration activities needed to improve the track system. The three projects address common maintenance operations, common rehabilitation operations and derailment repairs.

8. Test Planning--this project will develop a data collection plan for conducting FAST and in-service tests.

9. In-Service and FAST Tests--in this project the test plan developed in Project 8, will be implemented at various test sites.

10. Simplifed Structural Model--a structural model of the track system is to be developed which, computationally, will be more economical to operate than existing models.

11. Track Systems Analysis and Handbook Preparation--the results of the previous projects will be assembled into a track system model which will be exercised to develop information for the Handbook. The Handbook will be used to assess track performance, maintenance operations and costs, and ultimately to evaluate specifications for new components.

12. Results Dissemination and Evaluation-VersionII--dissemination and evaluation of this version of the handbook will be similar to Project 3.

Estimated R&D costs and schedule for developing the handbook are $5,684,000 and seven years, respectively.

B.1.2 Subprogram B--Improved Lateral Track Stability

Problem--Excessive longitudinal rail stress resulting from production, installation, track shift, wheel loads and temperature extremes can cause track to buckle or to pull apart. In 1976 there were 101 accidents attributed to buckling in which 44 people were injured. Presently, the railroad industry does not have simple or reliable means for determining when or where these problems will occur, nor are cost guidelines for track design available for preventing buckling problems.

Objective--Develop information which will allow railroads to reduce accidents caused by track buckling or by rail pull apart by 90 percent, and reduce unnecessary track restraint and maintenance by 10 percent.

State-of-the-Art--Several track buckling models have been developed, but not validated because buckling experiments for U.S. track conditions have not been performed.

There is currently no method for portable nondestructive measurement of in-situ rail longitudinal stress, although several approaches to the problem have been proposed.

R&D Projects Required--This subprogram is comprised of the following nine R&D projects:

1. Problem Definition Study--determine costs and techniques currently in practice for the preventing buckling and pull apart, and the conditions under which these failures occur.
2. Track Buckling Test Facility Design--establish requirements for a facility based upon data gathered in the Problem Definition Study.
3. Track Buckling Test Facility Construction.
4. Buckling Test Planning--establish test requirements aimed at determining those track parameters which will most economically prevent buckling and pull apart.
5. Buckling Tests and Analysis--conduct tests, analyze results, calibrate and validate models, and write a report suitable for inclusion as a section in the Track System Handbook.
6. Stress Detector Feasibility Studies--conduct studies of innovative technologies for the in-situ measurement of rail stress.

7. Stress Detector Prototype Development and Laboratory Test--develop and test the two most promising concepts, selected on the basis of accuracy, portability, simplicity of usage, etc.
8. Stress Detector In-Service Test and Evaluation--evaluate prototype accuracy, usage, and costs. Report results in a manner suitable for inclusion in the Track System Handbook.
9. Results Dissemination--produce a summary report, seminar and trade literature articles.

Estimated R&D costs and schedule are $1,303,000 and 3.8 years, respectively.

B.1.3 Subprogram C--Improved Rail Metallurgy

Problem--Various forms of rail wear, degradation, and failure are estimated to have caused 1,000 accidents in 1976 costing the railroads and shippers $63,000,000 and to have necessitated the replacement of 250,000 rails (39 foot length) at a cost of another $61,000,000.

Objective--Develop a rail such that wear life is increased at least by a factor of 2, probability of failure is decreased at least by a factor of 0.2, and price is increased no more than 10 percent above that of standard carbon rail (using 1978 dollars as a basis).

State-of-the-Art--There is little doubt that rail wear and failure properties can be improved substantially through metallurgy. The principal question is, can it be done at an affordable price to the railroads. The aims of researchers in other countries who have pursued improved rail metallurgy perhaps more vigorously than we in the United States, suggest that an affordable price might be achievable.

R&D Projects Required--Eight R&D projects comprise this subprogram:

1. Rail Demand Study--estimate near and long term rail demand as a function of price, rail wear, and failure properties.
2. Laboratory and FAST Tests--test alternative rail metallurgies to determine wear and failure properties.
3. Rail Supply Study--estimate expected price based on existing domestic and alternative production methods.
4. Production Method Evaluation--evaluate the cost-effectiveness of unproven production methods, if such a method is selected in Project 3.
5. Test Planning-develop plan for in-service and FAST tests of most cost-effective metallurgies.
6. In-Service and FAST Test--produce, install and test samples of improved rail in operational service and compare with standard rail.
7. Analysis and Report--estimate cost and performance of track structures using improved rail and those using standard rail.
8. Dissemination of Results--prepare report on subprogram results and use as a basis for convening a research utilization seminar for suppliers and other rail industry representatives.

The estimated R&D costs and schedule for this subprogram are $1,440,000 and approximately six years.

B.1.4 Subprogram D--In-Place Rail Hardening

Problem--Rail wear and various forms of degradation and failure are estimated to have resulted in 1,000 accidents in 1976 costing the railroads $63,000,000, and to have necessitated the replacement of 250,000 rails at a cost of another $61,000,000.

Objective--Develop a method for hardening rails in-place such that the wear life is increased at least by a factor of 1.5 and the probability of failure is decreased at least by a factor of 0.4 relative to standard carbon rail. Cost must be less than $5 per rail (1978 costs).

State-of-the-Art--Results of preliminary study indicate that it is technically feasible to flame harden or stress relieve rail in-place by towing an array of fuel gas torches along the track at constant speed. However, quality and consistency of flame hardened rails has not always been satisfactory, and the costs associated with the method are uncertain.

R&D Projects Required--This subprogram is composed of six R&D projects.

1. Heat Flow Analysis--predict the temperature at the rail and tie-plate interface and the tie and tie-plate interface when hardening rail in place.
2. Laboratory Test and Analysis--determine operating conditions and control that provide the best product in terms of consistency, wear, and failure properties. Estimate costs.
3. Prototype Equipment Specification--develop specification for in-place rail hardening equipment including vehicle subsystem, if required.
4. Prototype Equipment--design and construct prototype equipment specified in Project 3.
5. Field Tests and Analysis--conduct field tests, measure cost and performance, revise vehicle specifications and operating procedures as required.
6. Results Dissemination--produce summary report, seminar and trade journal articles to disseminate findings.

The estimated R&D costs and time table for this subprogram are $1,570,000 and 4.5 years.

B.1.5 Subprogram E--Improved Thermite Welding

Problem--The growing use of CWR has made field welding an increasingly troublesome problem. While in-plant welds are reliable and reasonably cheap, field welds are not. Thermite field welds fail anywhere from 3 to 100 times as often as in in-plant welds.

Objective--Improve thermite weld reliability to that of in-plant flash-butt welds at a cost differential of no more than $3.50 per weld (1978 costs).

State-of-the-Art--Thermite welding is a standard field welding technique used extensively in the U.S. Defective welds are common and appear to be due to inadequate training of field crews and lack of quality controls.

R&D Projects Required--This subprogram is composed of four projects:

1. Analysis of Current Procedures--identify and analyze cost-effective procedures and practices.
2. Improved Procedures--develop procedures and equipment (if needed) to improve cost effectiveness of thermite welds.
3. FAST and In-Service Demonstration--procedures and equipment developed in Project 2 will be be demonstrated on FAST and cooperating railroads.
4. Results Dissemination--produce report documenting results of subprogram; conduct seminar and training sessions to demonstrate new procedures.

Estimated R&D costs and schedule are $500,000 and slightly over 3.7 years.

B.1.6 Subprogram F--On-Site Electric Flash-Butt Welding

Problem--Electric flash-butt welding techniques are usually used in-plant to produce CWR of about 1/4 mile lengths. These lengths must then be joined on-site usually by thermite welds or other joining techniques. The unreliability and high costs of field welds are problems in many railroads.

Objective--Develop a field welding technique as reliable as in-plant flash-butt welding. Costs per weld should approximate in-plant welds, or about $10 to $30 per weld (1978 costs). Flash welding, which produces inexpensive, reliable welds in a plant has recently been tried in the field with some success. The process does, however, require removal of spikes and anchors so the rails can be pulled together, and a relatively large amount of upset material is produced. Removal of the upset material is relatively expensive.

R&D Projects Required--Four R&D projects are recommended for this subprogram:

1. Test Planning--develop plan for monitoring existing on-site flash-butt welds.
2. Cost-Effectiveness Study--monitor performance of existing on-site flash-butt welds and compare with cost and performance of thermite and other in-plant welds.
3. Shear Evaluation Study--monitor the performance of an automatic shear developed in the Soviet Union and develop modifications, if required.
4. Results Dissemination--publish report and conduct seminar on subprogram results.

The estimated R&D costs and schedule for this subprogram are $315,000 and approximately two years.

B.1.7 Subprogram G--In-Place Rail Welding

Problem--Jointed track, approximately 85 percent of all U.S. track, has much higher maintenance costs than CWR track. Maintenance costs could be substantially reduced if track could be welded in-place. Considering about 270 joints per mile of track, the cost of thermite welds would be prohibitive for in-situ conversion.

Objective--Test and evaluate methods to weld jointed rails while leaving them spiked and anchored. Cost of process should not exceed $50 per weld to be competitive with other welding techniques.

State-of-the-Art--Present in-field welding procedures all require spike and anchor removal. New techniques such as friction welding, electron-beam welding, and laser-beam welding may be attractive to the railroads, if they can be developed to the point where they can be more properly evaluated.

R&D Projects Required--Seven projects are recommended for this subprogram:

1. Market Study--evaluate trends and costs of CWR installations to determine market for in-place rail welding.
2. Survey of Techniques--identify techniques for in-place welds that do not require rails to be drawn together and determine adaptability for field use.
3. Laboratory Test Plan--develop evaluation plan for techniques found most favorable for field use.
4. Laboratory Tests--conduct laboratory tests of welding technique identified in Project 3.
5. Track Test Plan--design demonstration of recommended welding technique (Project 4).
6. FAST and In-Service Tests--conduct field test at FAST to determine reliability. If acceptable, conduct further in-service tests with various railroads.

7. Results Dissemination--publish findings in final report and hold seminar to describe new technique.

The R&D schedule and estimated costs for this subprogram are $620,000 and about four years, respectively.

B.1.8 Subprogram H--Bolt Hole Crack Prevention

Problem--Bolt holes in rail joints are a problem because cracks develop at the holes because of stress concentrations, the discontinuous track structure and the dynamic loading produced by the rail joints. In 1976 bolt hole cracks led to more than 100 train accidents and cost about $3 million in damage to track and equipment.

Objective--Develop a system for treating non-cracked bolt holes to eliminate future cracks.

State-of-the-Art--Bolt holes can be strengthened by various approaches including sleeve expansion, shot peening, and edge coining. Of these, sleeve expansion appears to be the most promising technique to prevent cracks.

R&D Projects Required--Three projects make up this subprogram which is directed at the treatment of serviceable bolt holes in place.

1. Test Plan--design demonstration of in-place bolt hole expansion to establish sleeve expansion capabilities and costs.
2. Demonstration--obtain in-track performance using FAST and other railroads to assess rail life with and without expanded bolt holes.
3. Results Dissemination--document demonstration results and conduct seminars for maintenance/rehabilitation personnel.

The schedule and estimated costs for these projects amount to nearly five years and $130,000.

B.1.9 Subprogram I--In-Place Bolt Hole Crack Restraint

Problem--Approximately 85 percent of total U.S. track is still jointed rail. Considering present and predicted CWR installation rates, jointed track will remain the predominant type in service within the foreseeable future. Nearly one bolt hole crack was detected for every two miles of track inspected in 1970.

If procedures could be developed to repair bolt hole cracks in the field, rail life would be extended, and rail replacement costs could be reduced.

Objective--Develop a system to repair bolt hole cracks to 1/2 inch in length at repair costs less than 25 percent of the rail replacement (in-field) costs.

State-of-the-Art--Bolt hole cracks can be repaired by the sleeve cold-expansion process. Various other techniques such as shot peening and edge coining have been suggested, but do not appear as promising as sleeve expansion. There is a need to conclusively demonstrate the effectiveness of sleeve expansion on cracked bolt holes.

R&D Projects Required--Five projects are recommended for this subprogram. Several may be combined and performed by a single contractor.

1. Test Planning--develop plans for both laboratory and in-service testing which can establish the performance of repaired bolt-holes.
2. Laboratory Testing--conduct lab tests to determine the largest size bolt hole crack that can be repaired by sleeve expansion.

3. Demonstration--validate laboratory test results at FAST by repairing and installing cracked rail segments obtained from railroads.
4. Crack Detection Guidelines--specify detection requirements for inspection equipment.
5. Results Dissemination--demonstration project findings will be documented in report format, trade journal articles, and via industry-wide seminars.

Estimated R&D costs and timetables are $710,000 and approximately 3.7 years.

B.1.10 Subprogram J--Improved Wood Tie Fastening System

Problem--The performance of rail-tie fastening assemblies is a matter of considerable economic concern to the railroad industry. Until recently, the conventional wood tie fastening system (tie plate, anchors, cut spikes) performed well on U.S. tracks. Increasing wheel loads and higher tonnage, however, appear to be taxing the performance of this system. Many train accidents attributed to track geometry defects can be traced to the rail-tie interface. In 1976, nearly 500 accidents were conservatively estimated to be fastener-related.

Objective--Develop information about currently available improved systems for fastening rails to wood ties which will allow the industry to save $3.0 million when using improved fastening systems costing no more than 44 percent more than conventional systems (1978 dollars).

State-of-the-Art--The variety of fastener designs in current use and testing in the world is staggering. In addition to conventional system variations, improved performance systems are even more diverse. These include, for example, lock spikes, screw spikes, compression clips, elastic clip tie plates, and elastic clips.

Improved tie fastening systems have been used more extensively in other countries. In the U.S., a variety of such systems are being tested at FAST and other railroads. Performance and cost data are lacking, thus restricting selection and installation recommendations for industry adoption.

R&D Projects Required--Seven projects are recommended which will provide information on improved fastening systems for wood ties, thus allowing the railroad industry to select those designs which ensure satisfactory and economical performance for localized track-train conditions.

1. Fastener Economic Study--conduct a preliminary economic assessment of the use of improved wood tie fasteners for various track/train conditions.
2. Laboratory Test Planning--develop plan for testing improved fastener systems in laboratory.
3. Laboratory Testing and Analysis--conduct laboratory tests identified in Project 2.
4. Test Planning--develop plan for conducting FAST and in-service tests of most promising fastener systems determined in Project 3.
5. In-Service and FAST Tests--collect load, climatic, and degradation data specified in the test plan.
6. Analysis and Report--estimate benefits achievable by using the highest performing fastening system in a variety of track configurations.
7. Results Dissemination--prepare report documenting test results and analyses and conduct research utilization seminar.

The R&D schedule and cost estimates for this subprogram are six years and $1,665,000.

B.1.11 Subprogram K--Improved Wood-Based Tie

Problem--Based on figures provided by the railroads, it is estimated that Class I railroads inserted 25.6 million new ties in 1978. In 1979, these same railroads will probably install about 27 million crossties. Such volume accounts for a sizeable part of the total maintenance of way budget annually (about 17 percent in 1978).

Timber ties are the mainstay of the industry accounting for more than 99 percent of all ties in place during 1977. Nevertheless, timber ties deteriorate due to natural forces as well as increasing wheel loads. Tie crushing, splitting, plate cutting and spike-killing are examples of deterioration modes due to natural and man-made forces.

Sharp increases in the price of timber ties, supply uncertainties, heavier wheel loads, and alternative technologies suggest a detailed review of the role of timber ties in new track systems.

Objectives--Increase the useful life of newly inserted wood (or wood-based) crossties by at least 33 percent relative to existing conventional hardwood ties at a price differential of not more than $1 per tie (1978 costs).

State-of-the-Art--Recent government and industry studies cast some doubt on the ability of timber tie producers to meet expected demand by railroads. Various technologies and procedures are in use today to extend tie life either by reducing decay rates or damage caused by increasingly heavier wheel loads. Bonded or laminated ties and others developed from wood chips are being tested under operational conditions at FAST and other railroads.

R&D Projects Required--Six R&D projects are recommended:

1. Timber Tie Supply Study--estimate the availability and price of timber ties through the year 2000.
2. Preliminary Analysis of Alternative Wood-Based Ties--select the most promising alternative wood-based ties currently being tested and conduct preliminary cost-performance study.
3. Test Planning--develop test plan for in-service and FAST testing of viable wood-based tie alternatives.
4. In-Service and FAST Tests--conduct tests specified in Project 3 and obtain load, climatic and degradation data.
5. Analysis and Report--establish the best wood-based tie alternative to use under different track system and environmental conditions.
6. Results Dissemination--document the results of all projects and conduct research utilization seminar for suppliers and other railroad representatives.

Estimated R&D costs and timetable for the overall subprogram are $885,000 and about 4.3 years.

B.1.12 Subprogram L--In-Place Repair of Spike-Killed Ties

Problem--Despite the fact that timber ties have been improved sufficiently over the years to withstand competition from other materials and methods, timber ties deteriorate. In addition to normal decay, heavier wheel loads have accelerated tie deterioration due to crushing, plate cutting, splitting and spike-killing.

It has been estimated that about 15 percent of all ties removed each year are removed because of spike-kill. Accordingly, U.S. railroads spent about $80 million in 1978 to replace some 4.5 million spike-killed ties.

Objective--Verify, through experiments, that in-place application of available chemical filling materials can extend the life of spike-killed ties by eight years at a cost of $0.30 per tie in (1978 costs).

State-of-the-Art--Repair of spike-killed ties presently involves driving a peg or dowel into the spike hole and re-spiking. Recently, various chemical filling agents have become available which are claimed to be able to restore and retain 80 percent of spike-tie bond at a cost per tie of $0.25. While operational tests on various railroads are in-progress, data are inadequate for industry-wide recommendation.

R&D Projects Required--Four projects are included in the subprogram:

1. Test Planning--design laboratory, FAST, and in-service tests to collect information on spike holding power under various traffic and environmental conditions.
2. Laboratory and FAST Tests--conduct laboratory and FAST tests to provide preliminary determination of chemical filler materials performance.
3. In-Service and FAST Tests and Analyses--based on Project 2 results, conduct expanded in-service tests of chemical filler materials.
4. Results Dissemination--summarize project results into final report and conduct various research utilization seminars to disseminate results to railroad maintenance and management staff.

The costs and timetable to complete this subprogram are: $410,000 and approximately 3.7 years.

B.1.13 Subprogram M--Improved Concrete Tie and Fastener Selection and Utilization

Problem--Less than one percent of all ties in-place in the U.S. are concrete ties. Most of these have performed reasonably well to date. Yet data does indicate that some areas of the concrete tie track system require further research. One problem area has been the rail fastener which has resulted in pad movement, excessive vibration, insulator breakage, tie skewing and rail creep. Knowledge of optimum track system parameters (e.g., tie spacing, ballast type and depth, ballast degradation and anchorage requirements) for given track conditions is also inadequate.

Objective--Determine if concrete tie track has at least 100 percent greater tie life, 50 percent lower maintenance costs, and 40 percent higher rail wear life relative to conventional wood tie track.

State-of-the-Art--Although concrete tie performance in field tests conducted prior to 1970 was relatively poor, experience with ties made to new specifications has been good to date. The U.S. is capitalizing on the experience of foreign railroads and is presently developing design specifications and laboratory test plans for heavier wheel loads.

R&D Projects Required--Six R&D projects have been identified for this subprogram:

1. Laboratory Test Planning--develop plan for laboratory testing of concrete tie/fastener systems including establishment of requirements for test duration, data reduction and analysis.
2. Laboratory Testing and Analysis--perform the required laboratory tests developed in Project 1.

3. Test Planning--develop plan for conducting FAST and in-service tests for the more promising tie/fastener systems analysed in Project 2.

4. In-Service and FAST Tests--perform the required in-service and FAST tests according to the test plan specifications developed in Project 3.

5. Analysis and Report--estimate cost and performance parameters of leading concrete tie/fastener system candidates in various track configurations and compare with conventional wood tie/fastener systems.

6. Results Dissemination--summarize the results of previous projects in a final report and conduct research utilization seminars.

The estimated R&D costs and schedule to complete this subprogram are: $1,900,000 and a little over six years.

B.2 PBQ&D Subprograms

The PBQ&D subprogram information was obtained from the PBQ&D study report. Much of the text that follows is reproduced verbatim from the PBQ&D report without further attribution.

B.2.1 Subprogram N--Bridge Inspection, Rating and Evaluation of Remaining Life

Problem--Many railroad bridges now in use date back to the last century. That they are still able to carry today's heavier loads at increased speeds is a tribute to the conservativeness of their design and the quality of materials and workmanship used in their construction. However, many of these old bridges, and others built more recently, have been victims of decades of deferred maintenance as has the balance of the railroad infrastructure. Therefore, there is growing concern regarding the ability of bridges to carry increasing loads at higher speeds and often loads on bridges and/or speeds are restricted, sometimes unnecessarily. Thus, the need exists for more adequate information on bridge condition and better techniques for rating bridges in order to make better operating decisions. This pertains also to decisions concerning remaining life and whether to continue a bridge in service, rebuild it, or replace it.

Objective--Develop improved techniques and tools for determining present bridge conditions and improved rating procedures in order to evaluate more adequately bridge safety in handling present loads, ability to handle increased loads in many instances, and remaining bridge life.

State-of-the-Art--Cooper E loadings and corresponding bridge ratings, developed for steam locomotive-drawn trains, are widely used today for rating bridges for diesel locomotive-drawn trains. The AAR and some railroads have developed computer programs for rating selected types and spans of truss and girder bridges in conformance with the AREA specifications.

R&D Projects Required--Five R&D projects have been identified for this subprogram:

1. Inspection Methods for Rating and Evaluation--develop improved procedures, tools and instruments for inspecting steel, concrete and timber bridges for purposes of rating and estimating static (service) and dynamic fatigue life.
2. Routine Inspection Methods--develop improved procedures and tools which can be used by railroad maintenance personnel to routinely inspect bridges; determine proper inspection frequencies for various bridge and loading conditions.
3. Bridge Rating--study and develop improved methods for rating various types of bridges to determine their ability to carry contemporary loads.
4. Static (Service) Life Estimation--develop a method to determine the remaining static life of various types of bridges which takes into account current condition and expected material deterioration rates assuming routine maintenance will be performed when necessary.
5. Fatigue Life Estimation--develop a method of estimating the remaining fatigue life of bridges which takes into account the current condition, past and projected loads, and expected maintenance practices.

The cost and timetable to complete this subprogram are: $4,050,000 and three years respectively.

B.2.2 Subprogram O--Subgrade Stabilization and Improvement

Problem--Much of the track in use today was built in the last century and still contains a variety of problems related to the subgrade in terms of soft spots, sinks, unstable and settling embankment fills, unstable cut slopes, poor drainage and stretches of weak subgrade that require excessive maintenance.

In many cases railroad maintenance funds were spent mostly on track structure, deferring maintenance of the subgrade that resulted in further deterioration of weak subgrades. In other cases routine maintenance was provided without a definitive goal for development of a permanent stabilization method.

The combination of the above factors has resulted in today's subgrade problems. "Roadway Maintenance" accounted for about five percent ($146 million) of the 1976 expenditure for maintenance of way and structures. It is estimated that ten percent of this amount was subgrade related. Much of the surfacing in Account 220, "Track Laying and Surfacing: (TL&S) can be attributed to poor subgrade. It is conservatively estimated that about 15 percent of the three quarters of a billion dollars spent in 1976 on TL&S, or $112.5 million, can be attributed to poor subgrade. A total of 160 accidents causing approximately $6.4 million damage was attributed to roadbed defects in 1976 and it is estimated that 20 percent of this amount was due to poor subgrade.

Objective--Develop economical and practical methods to salvage, strengthen and stablize deficient subgrades with respect to various subgrade materials to prevent settlement, slipouts, slides, heaving and subgrade pumping.

State-of-the-Art--Many weak subgrades, particularly in cohesive silts and clays, are successfully treated by using lime injection techniques. However, some failures are experienced in lime-treated subgrades which indicate that one single stablization technique cannot solve all subgrade problems.

The problem of pumping can be successfully treated by using proper drainage with some filter barrier between the subgrade and the ballast. Various filter fabrics are in use today for this purpose. However, these fabrics are not always the most durable material and can be damaged, especially if the ballast is laid directly over the fabric.

Inadequate subgrade and surface drainage is the single most important cause for all the subgrade problems described above. If positive drainage can be provided to keep the subgrade relatively dry, much of the subgrade-related problems will be solved. Excessive moisture weakens the subgrade, aggravates pumping action, helps form ice lenses and reduces shear strength of cohesive soils resulting in reduced sugrade support. Regular maintenance of side ditches in most of the areas and provision of subgrade drainage in specific areas help alleviate excessive moisture problems.

R&D Projects Required--Five projects are recommended which will provide information on the most cost-effective methods of evaluating and correcting subgrade problems.

1. Evaluation Methods--develop methods for determining subgrade soil characteristics and for determining the support capability of various subgrade materials.
2. Stabilization Guidelines--develop guidelines or procedures which would allow railroad personnel to select the most cost-effective method for stabilizing the subgrade in problem areas; consider chemical, mechanical, barrier and moisture reduction methods.

3. Heating Reduction Guidelines--develop design guidelines which will allow railroad personnel to eliminate or significantly reduce heating and freeze-thaw softening of subgrades.
4. Pumping Reduction Guidelines--develop guidelines for using filter fabrics and other subballast filter gradation techniques for protecting various fine-grained subgrade soils.
5. Drainage Guidelines--develop improved methods, tools and materials for maintaining and restoring existing drainage facilities, and develop guidelines for their use; develop guidelines for installing new drainage facilities.

The R&D time and cost for this subprogram are four years and $4,500,000.

B.2.3 Subprogram P--Timber Cross Tie Rehabilitation and Disposal

Problem--The General Accounting Office has projected the annual needs of the railroads to be 40 million ties annually over the next ten years. The American Railway Engineering Association committee on ties and wood preservation has forecast a need for 30 million ties annually for the years 1980 through 1983.

There is no question that many ties could be repaired and reused, particularly those removed for plate cutting, splitting and spike-killing. To date, however, tie cost of removal, repair, and replacement has been too high to be economical. With the cost of ties increasing, as well as that of labor, the rehabilitation of ties must be reviewed and further efforts put forth to improve the means and methods.

Some unusable ties are either sold or given away. The market for full length ties is excellent while that for the "shorts" or 3-piece is very limited. The sale of ties presents some problems to the railroads because of the liability to the railroad if persons are permitted to enter the railroad's property to pick up the ties. Also, there is an accounting problem in connection with sale of ties.

In large cities and terminal areas ties are loaded in cars and hauled to disposal areas. This can be quite costly, but is done because of both potential hazard when left along tracks and possible vandalism.

Ties can be chipped by a machine which operates on the track and spread along the railroad right-of-way, however, leaching of the preservative presents environmental problems and the chips themselves become a fire hazard.

The use of ties for fuel is limited and no commercial use is known at this time.

Objective--Develop acceptable methods for rehabilitating timber cross ties in-place or at a plant site and for disposing of ties that are no longer serviceable.

State-of-the-Art--As indicated earlier, there is no question that ties can be repaired. Tie renewal is an accepted practice in the Soviet Union and some Western European countries. Their approach however, involves cascading the ties, i.e., taking them out of track after a short period of time (seven to ten years), totally resurfacing and retimbering the track, and retiring the removed ties after minimal repair, if necessary, to secondary or more lightly loaded track.

A recent study suggests that tie rehabilitation might well be economical in the United States and that an experiment is warranted.

It appears that little is known about acceptable tie disposal techniques.

R&D Projects Required--This subprogram is composed of ten projects which are described briefly below.

1. Plate Cutting Analysis--determine the theoretical and practical limits beyond which a plate cut tie can no longer function as a support for the loads imposed on the rail.
2. Plate Cutting Repair Evaluation--test and evaluate existing methods of repairing plate-cut ties, and develop, test and evaluate new methods; consider both field and in-plant methods.
3. Splitting Analysis--determine the limits beyond which it is no longer economical to rehabilitate a split tie.
4. Splitting Repair Evaluation--test and evaluate methods of repairing split ties; develop, test and evaluate new methods; consider both field and in-plant repairs.
5. Rehabilitation Analysis--develop guidelines for selecting ties for complete rehabilitation.
6. Rehabilitation Plant Study--determine the size and location of the market for rehabilitated ties; determine candidate sites for tie rehabilitation plants; estimate plant construction and operating costs.
7. Tie Removal Analysis--determine the total cost of removing ties from track in one piece or in three pieces; including subsequent lining and surfacing costs.
8. Reconstituted Tie Analysis--investigate further the use of discarded ties as material for manufacturing reconstituted ties.

9. Unrepairable Tie Market Analysis--analyze the market for unrepairable one-piece and three-piece ties; estimate number of such ties available and suggest a selling price.

10. Useless Tie Disposal Methods--develop an economical and environmentally acceptable method of disposing of useless ties.

Estimated R&D costs and time for this subprogram are $2,100,000 and three years.

B.2.4 Subprogram Q--Special Trackwork Maintenance

Problem--In 1976, 842 train accidents were attributed to special trackwork on Class I and Class II railroads, constituting about twenty percent of the total 4,260 accidents related to track, roadbed and structures.

Damages to track and equipment amounted to $7,218,000, or 8.4 percent of the total cost of all accidents in this category. This figure does not include accident clean-up costs, damages to lading, or intangible costs related to train delays, inability to meet schedules and loss of business to competing modes.

Objective--The objective of this research is to analyze the various problems encountered in the maintenance of special trackwork, and to develop improved maintenance methods.

State-of-the-Art--A study has recently been published by AREA Committee #22 to develop a system for computing relative maintenance workload values on various track sections. It is entitled "Developing the Maintenance Workload and Force Requirements Using a Modified Equated Mileage Parameter Taking into Account the Various Variables". This study updates and refines a former study on comparative track values. Some additional work on innovative approaches to frog and switch design has also been done with the aim of reducing maintenance requirements.

R&D Projects Required--Six R&D projects comprise this subprogram.

1. Switch Point Design Evaluation--evaluate various switch point materials and shapes with the aim of determining those which tend to minimize overall cost including cost of materials, installation, maintenance and accidents.
2. Stock Rail Design Evaluation--evaluate various stock rail materials, shapes and fastening system designs with the aim of determining those which tend to minimize overall cost including cost of materials, installation, maintenance and accidents.
3. Frog Design Evaluation--evaluate various frog materials, shapes and installation practices with the aim of determining those which tend to minimize overall cost.
4. Guard Rail Shape Evaluation--determine optimum geometric shape or taper of guard rail flares.
5. Switch Maintenance Method Evaluation--evaluate various tools, machines and methods of maintaining switches with the aim of minimzing overall cost.
6. Track Geometry Maintenance at Special Trackwork--develop and evaluate improved components, installation techniques and practices, gauges, and maintenance practices with the aim of maintaining proper track geometry at minimum overall cost.

The estimated R&D cost and time for this subprogram are $3,400,000 and six years.

B.2.5 Subprogram R--Bolted Joints

Problem--Bolted joints have always caused problems, hence the accelerating trend to CWR. Bolts become loose and even fall out; joint bars break; bars and the rail wear, especially when the joint gets loose; and defects in the rail occur at a much greater frequency within the joint bar area than they do outside this area. Rail end batter is a unique problem with bolted joints.

Insulated joints also cause problems. They are necesary at the ends of signal circuits and cannot be replaced by welds. The insulating materials used in these joints are subject to accelerated wear and in some heavily travelled areas must be replaced every few months. When insulated joints get loose and dirt gets in, component wear accelerates.

Objectives--The objective of this effort is to develop improved designs and maintenance methods to upgrade performance of bolted joints and to prevent premature joint bar breakage. The research will address inadequate insulated joint performance, inadequate non-insulated joint performance, premature joint bar breakage and inadequate joint maintenance methods.

State-of-the-Art--Bolted joints are used in most turnouts for convenience of field installation and replacement of worn components. Bolted joints are mandatory for insulated joints. Therefore, bolted joints are a fact of life for railroads and their design and maintenance are of paramount concern. Bolted joints represent a discontinuity in the rail and even the strongest designs are less strong and stiff than the rail itself. This reduced strength and stiffness of bolted joints, especially with poor ballast and subgrade support, combine with high center-of-gravity cars and truck centers that coincide with the 39-ft length of rail to cause the present-day phenomenon of "rock and roll" when staggered joints are prevalent. Heavy, 100-ton cars accentuate joint problems.

The practice of bonding insulated joint with epoxy adhesives, although considerably more costly originally, shows promise for greatly increasing the life of insulated joints.

R&D Projects Required--This subprogram is comprised of four projects.

1. Insulated Joint Design Evaluation--evaluate various materials, designs and installation practices with the aim of minimizing overall cost including procurement, installation, maintenance and accident costs; include both glued and non-glued joints.
2. Insulated Joint Maintenance--develop and evaluate improved tools and practices for inspecting and maintaining insulated joints with the aim of minimizing overall cost; document and promote the most cost-effective results.
3. Non-Insulated Bolted Joint Design Evaluation--evaluate various materials, designs and installation practices with the aim of minimizing overall cost.
4. Non-Insulated Bolted Joint Maintenance--develop and evaluate improved tools and practices for inspecting and maintaining non-insulated bolted joints with the aim of minimizing overall cost.

Estimated R&D cost and time for this subprogram are $2,2000,000 and three years.

B.2.6 Subprogram S--Ballast Fouling from External Sources

Problem--Ballast fouling from external sources magnifies the problems created by other fouling mechanisms such as sand and mud pumping, upward percolation of subgrade, and abrasion of ballast pieces during the passage of trains. Wet, dirty ballast contributes heavily to the loss of line, surface, and superelevation. Track geometry must periodically be restored through spotting, smoothing, surfacing and reballasting operations.

Fouled ballast must either be cleaned periodically with expensive ballast cleaning equipment, plowed from under the track, cleaned and replaced, or the track must be raised on new ballast while retaining the old ballast as sub-ballast. Because of the obvious costs involved in maintaining ballast in prime condition, these procedures are often neglected.

Fouling from extenal sources is estimated to have cost the railroads $37 million in 1976.

<u>Objective</u>--Develop cost-effective methods for controlling or preventing ballast fouling from external sources and for cleaning fouled ballast.

<u>State-of-the-Art</u>--A sufficient depth of clean, well-drained ballast under all ties is a vitally important element of sound railroad track that can be maintained at minimum cost. A clean ballast section is necessary to provide a firm bearing for the ties, to evenly distribute wheel loads over the subgrade, to provide drainage to the track structure, to inhibit the growth of vegetation, and to provide track stability in the longitudinal, lateral, and vertical planes. When fouling occurs, fines fill the voids in ballast, destroying the drainage capability and providing a soil for the growth of vegetation. Moisture pockets often form in the ballast voids, contributing to frost heaving, physical and chemical deterioration of some types of ballast, and eventually to the general deterioration of ties, rails and fastenings. Moisture-laden fouled ballast loses its ability to evenly distribute the loads. Permanent deformation may occur as the ballast is forced into the subgrade.

<u>R&D Projects Required</u>--Three R&D projects are recommended for this subprogram.

1. Airborne Dust, Dirt and Sand Control--conceive and evaluate alternative approaches to prevent wind-blown particles from accumulating on the track and from spreading into and fouling the ballast; consider trees and shrubs, fences, ditches and dikes, spraying with petroleum, covered shelters, and moving adjacent fouling sources to the leeward side of the track.

2. Waterborne Soil and Sediment Control-- conceive and evaluate alternative methods for diverting or preventing sediment-laden water courses from encroaching upon the track structure; consider methods of increasing vegetative cover, improving drainage, and cleaning culverts and bridge openings.

3. Ballast Cleaning Methods Evaluation--conceive and evaluate alternative approaches for cleaning fouled ballast, test and compare various methods of shoulder cleaning, undercutting, sledding and plowing, and surface raises.

The estimated R&D cost and time for this subprogram are $1,420,000 and three years.

B.2.7 Subprogram T--Switch Point Wear Limits

Problem--The permissible limits of switch point wear, chipping, and spalling are presently determined by track personnel in a very subjective manner. Manuals, gauges, guidelines, and/or procedures are not available to assist the track inspector in determining the need for repair or replacement of switch points and related track components. Maintenance practices seem to vary widely throughout the railroad industry. Track inspection over a single railroad line has often revealed wide variations from point to point as to the limits of wear. These differences may frequently be attributed to a lack of experienced track personnel who are assigned to inspect switches.

Objective--The objective of this research is to develop improved methods for assessing switch point wear and condition, including the design of gauges for determining the allowable limits of switch point wear; and to obtain more knowledge regarding the cost and performance of special trackwork so that better design and maintenance decisions can be made.

State-of-the-Art--The pressure which should be exerted by a switch point against a stock rail in the closed position to permit the safe passage of trains is not exactly known. Strain gauge measurements on the switch stand connecting rod have been made by the AAR Engineering Division Research Staff for the Canadian National Railroads, but were never published. These results indicated that there is an appreciable change in the force applied by the connecting rod when the wheels pass from the stock rail to the switch points, or from the point to the stock rail.

Sufficient information is not currently available on the desired degree of looseness of connections between the switch stand, connecting rods, and main and common rods and their connections to the switch points. The required degree of tightness of connections at power switches has not been adequately assessed.

Railroads have not been adequately informed of the cost and performance comparisons for special trackwork of "regular" components versus the improved metallurgical components. These include the heat-treated and alloy components for switch points, frogs, guard rails, etc. Other items include manganese inserts for switch points and frogs, Samson switch points, and hardened (press or explosive) manganese steel components. Detailed cost-benefit analyses have not been developed for these longer-life components.

R&D Projects Required--This subprogram is comprised of the following seven projects.

1. Special Trackwork Accident Study--determine the number and causes of accidents (derailments and collisions) that have occurred on various types of special trackwork in the past five years.

2. Current Practices Study--evaluate the methods, tools and gauges used by various track personnel for identifying the need for repair, removal, or weld build-up of switch points; evaluate various techniques for switch point maintenance and adjustment.
3. Switch Point Wear Tests--determine switch point wear rates under various loading conditions.
4. Lateral Switch Point Pressure Tests--develop a better device for measuring the lateral force exerted on the stock rail by the switch point; measure the force in the unloaded condition for a variety of switch points and connecting rods.
5. Switch Point Inspection Procedures--determine optimum inspection frequency for different traffic densities and degrees of curvature; develop standard gauges for determining wear limits; prepare an inspection procedures manual.
6. Special Trackwork Wear Tests--determine the useful life and performance characteristics of various "improved" special trackwork components.
7. Special Trackwork Cost-Benefit Analysis--determine costs and benefits of using various "improved" components under a variety of conditions.

Estimated R&D cost and time are $1,400,000 and five years.

APPENDIX C

TECHNICAL REVIEW PANEL MEMBERS

TECHNICAL REVIEW PANEL MEMBERS

G. H. Way--Association of American Railroads

R. M. Brown--Union Pacific **Railroad**

W. S. Simpson--Southern Railway Company

C. E. Godfrey--Abex Corporation

W. R. Hamilton--Portec, Incorporated

R. E. Kleist--FRA, Office of Federal Assistance

J. A. Richard--FRA, Northeast Corridor Project

P. Olekszyk--FRA, Office of Research and Development

R. A. Smith-- U.S. DOT, Transportation Systems Center

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US DOT, FRA, Marcel J Zobrak

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