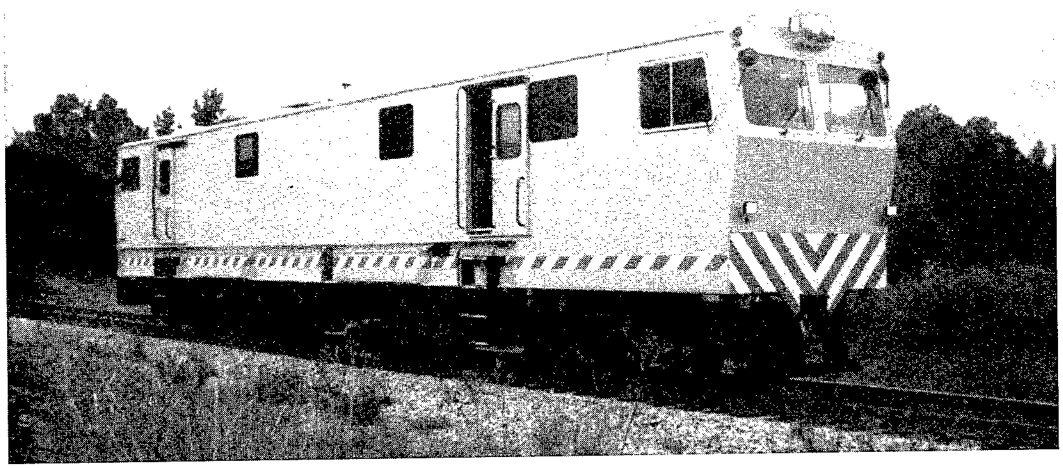
U. S. Department of Transportation
Federal Railroad Administration

FEASIBILITY STUDY ON THE REPLACEMENT OR UPGRADE OF THE T-6 TRACK RESEARCH VEHICLE

PB98-144645

Office of Research
and Development
Washington, D.C. 20590

U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Cambridge, MA 02142-1093



DOT-VNTSC-FRA-98-5

Interim Report
March 1998

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
March 1998

3. REPORT TYPE AND DATES COVERED
Interim - December 1997-March 1998

4. TITLE AND SUBTITLE
Feasibility Study on the Replacement or Upgrade of the T-6 Track Research Vehicle

5. FUNDING NUMBERS
R8010/RR819

6. AUTHOR(S)
John Choros, Andrew Sluz, and Gary Carr

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Cambridge, MA 02142-1093

8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-FRA-98-5

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Railroad Administration
Office of Research and Development
400 7th Street, SW
Washington, DC 20590

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
For FRA internal use

12b. DISTRIBUTION CODE

13. ABSTRACT:
This feasibility and cost study concluded that the FRA's aging T-6 car be replaced with a new state-of-the-art research platform costing approximately $3.5 million. The new, Track Research Instrumentation Platform (TRIP) is envisioned as a laboratory on wheels. This vehicle will provide: the means to assess the geometry and structural safety of railway track, a research platform to develop and evaluate emerging technologies and the capability for evaluating newly implemented performance-based standards. Researchers and inspectors will have an environment with sufficient computational power to perform data acquisition and analysis related to field testing, track geometry measurement, and GPS information, as well as an adequate working environment to conduct research/inspection activities. The TRIP vehicle will include the following proven inspection/research techniques; Gage Restraint Measurement System, Instrumented Wheel Sets, Track Geometry System, Global Positioning System, and Rail Profile Measurements.

14. SUBJECT TERMS
Benefit/cost, Track Research Vehicle, Upgrade, Track geometry, Vertical stiffness, Inspection, Safety, Research Platform

15. NUMBER OF PAGES
40

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

PREFACE

This study is to evaluate the feasibility and cost of upgrading or replacing the existing Federal Railroad Administration's T-6 Track Geometry and Gage Restraint Measurement System/ Research vehicle with a state-of-the-art Track Research Instrumentation Platform (TRIP). This new vehicle would perform all existing tasks and/or test support that the T-6 is providing and would incorporate new evaluation techniques to improve assessment of track safety and/or developing and evaluating new safety inspection techniques. Changes in operating environment, traffic concentration, and higher speeds, and a combination of the three have created an environment where manual safety inspections are more difficult. Changes in inspection modes from manual/subjective to automated/objective provided by this new research vehicle will improve the overall track system safety.

The improvements in inspection techniques that will be developed through application of the research vehicle are expected to improve the efficiency of detection of track defects with increased safety to track maintenance forces. The improved efficiency in locating and correcting track defects will result in a reduction in derailments and track accidents.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (ha) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

°C=5/9(°F - 32)

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

°F=9/5(°C) + 32

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES 0 1 2 3 4 5
CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

Updated 8/1/96

TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

A feasibility and cost study was conducted to evaluate requirements for refurbishing or replacing the Federal Railroad Administration's rail-bound research platform. The study concluded that the FRA's aging T-6 car should be replaced with a new state-of-the-art research platform costing approximately $3.5 million. Technical considerations based on the FRA's current and future research requirements were the main criteria leading to this conclusion.

The new Track Research Instrumentation Platform (TRIP) is envisioned as a laboratory on wheels. This vehicle will provide the following: the means to assess the geometry and structural condition of railroad track, a research platform to develop and evaluate emerging technologies, and the capabilities for evaluating newly implemented performance-based standards. Researchers and inspectors will have an environment with sufficient computational power to perform data acquisition and analysis related to field testing, track geometry measurement, and GPS information, as well as an adequate working environment to conduct research/inspection activities.

At a minimum, the TRIP vehicle will include the following proven inspection/research techniques: Gage Restraint Measurement System, Instrumented Wheel Sets, Track Geometry System, Global Positioning System, and Rail Profile Measurements. Additional capabilities currently under development include Vertical Track Stiffness, Track Analyzer, Subgrade Assessment, and Digital Track Imaging. Each of the major systems will be studied to determine how state-of-the-art components match FRA's inspection requirements based on the newly revised safety rules.

In section 7, the cost/benefit analysis considers initial vehicle construction costs and operational costs for a five-year window. Each vehicle configuration option was evaluated based on cost and FRA's technical needs. Cost between upgrading the existing T-6 vehicle and replacement with a new research vehicle is in favor of the replacement option. The age of the T-6 (nearly 50 years old) was an important consideration in the analysis and recommendations. In addition, the configuration chosen will allow for increased productivity with lower maintenance costs.

The TRIP configuration selected will provide FRA with additional capabilities to meet the agency's strategic goals which are to promote and improve the safety of the national railroad transportation system, to advance technological innovation in railroad transportation through leadership and partnership, and to strengthen the economic vitality of the railroad industry. These goals are achievable through comprehensive research and development programs to provide a rational and effective basis for safety regulations and standards. The TRIP vehicle will provide the testing and evaluation abilities to achieve these goals.

1. INTRODUCTION

The Railroad Safety Act of 1970 as amended (CFR 49-II) vests broad powers in the Federal Railroad Administration (FRA) to regulate all matters affecting railroad safety. In response to this statutory mandate, the FRA has established track safety regulations and standards to ensure public safety. The FRA's Office of Research and Development (R&D) has in turn, instituted comprehensive programs to provide a rational and effective basis for these regulations and standards, and the revisions, thereof. Research is also conducted to aid in effective track inspection and verifying of track-related safety hazards. Further, research is conducted to implement specific recommendations of the National Transportation Safety Board concerning the safety of railroad track.

More recently, the FRA has annunciated a set of strategic goals. The FRA Office of R&D performs research and development to support FRA Strategic Goals:

Goal 1 - Safety: Promote and improve the safety of our national rail transportation system.
Goal 2 - Technological Advancement: Advance technological innovation in rail transportation through leadership and partnership.

Currently track research activities are pursued in the following broad areas:

- Track Structures
- Track/Train Interaction

In its efforts to ensure public safety, the FRA must be able to effectively assess the quality of all existing railroad track and operating equipment. Recent trends in the railroad industry indicate three major factors that strongly affect the integrity of current track structure:

- higher track usage where more car loads occur on the same or an even lower amount of track;
- higher axle loads to improve car load productivity; and
- less track time available for maintenance activities.

To objectively and reliably monitor the condition of all railroad track, continuous re-evaluation and updating of existing safety standards is required. The current emphasis strongly relies upon manual and automated inspection techniques to ascertain the track integrally. Additional track usage by the railroad industry necessities the development and use of performance-based standards to ensure track safety. To maintain a cutting edge in safety technology, predictive models are needed to anticipate potential problems before they lead to catastrophic failures.

2. HISTORICAL BACKGROUND

Existing FRA Research Vehicles

FRA maintains a significant stock of equipment (including FRA-owned railroad vehicles T-6 and T-10) which is used to support track research. This equipment, a result of the instrumentation and data processing advancements that are uniquely applicable to the railroad environment, has been developed under the track research program. The equipment is stored and maintained under a task-order type contract for Operation Maintenance Instrumentation and Analysis (OMI&A) Support for Railroad Research and used as Government Furnished Equipment (GFE), as required. This arrangement has served the needs of the FRA well, both in the timeliness and economy of track data collection.

In the past, FRA's Office of Research and Development operated numerous research vehicles to develop technologies pursuant to its mission, particularly for track inspection and rail flaw detection, and to collect data for vehicle/track interaction studies. These vehicles included the self-propelled electric multiple-unit cars Tl/T3 and T2/T4 which were used to develop the original automated track geometry inspection technology and then transferred out of R&D to FRA's Office of Safety to support track safety standards enforcement efforts.

Another FRA vehicle, T-10, was built in 1978 by modifying a Budd self-propelled diesel car. T-10 has never had an R&D role but has been used exclusively to perform the Automated Track Inspection Program (ATIP) in support of the FRA Office of Safety. The Office of Safety is considering replacement of this vehicle due to the high cost of maintaining an old, one-of-a-kind rail vehicle.

The hi-rail trucks, R2 and R3, were used in the late 1970's to develop ultrasonic rail flaw crack detection technology, and to assess the feasibility of using hi-rail vehicles to measure track geometry. The R-2 truck was transferred to the Transportation Technology Center (TTC) and is operated by the Association of American Railroads (AAR). R-3 was decommissioned in 1985, and a recent evaluation of the vehicle concluded that refurbishment for return-to-service is not recommended, based on the current mission requirements and cost.

A wayside testing van was used from 1978-1983 as a test equipment shelter and test monitoring station for tests on lateral track strength and other field tests. The van was decommissioned following the tests.

The only currently operational R&D vehicle is the T-6, the car body which dates back to the 1950's. Interchange rules prohibit freight cars built before 1957 (whether refurbished or not) from operation on the national rail system. The T-6, originally a hospital car, is not covered by these rules, however its age must be put into perspective when making decisions concerning its further upgrade. It began as a special test vehicle and was used as a track-geometry and safety-enforcement vehicle until the mid 1970's. It was decommissioned for a period of years and was reactivated in the mid 1980's as the developmental test bed for the Gage Restraint Measurement technology.

Over the years, the T-6 was also used for developing rail flaw detection systems; developing gage restraining measuring system; collected track and vehicle data in support of track strength measurements; collected data used in vehicle dynamics analysis and derailment studies; and collected data on vehicle track (instrumented wheels) interaction.

FRA's Office of R&D has had under its control research vehicles dedicated to the development and testing of track geometry, track strength measurement, rail flaw detection and vehicle/track interaction, etc. New technology, both in sensor design and computing power, allows a single vehicle to combine all of these functions, while still providing capacity and flexibility for further expansion, as technology advances. A new research vehicle designed with data networks and modular expansion capability can fulfill all of the historical FRA track research functions at minimal cost.

With the addition of a new research vehicle to the FRA's inventory of specialized equipment and contractor technical support services, the FRA will be able to maintain the capabilities to independently evaluate track and structure integrity issues through quick-response instrumentation, field test support, and materials testing under operating conditions. Such capabilities also provide much needed information and support to the FRA's Office of Safety. Replacement of the T-6 with a state-of-the-art Track Research Inspection Platform (TRIP) is therefore necessary for both current and future FRA effectiveness in pursuing its mandate of ensuring public safety.

3. CURRENT AND FUTURE RESEARCH NEEDS

FRA's Office of R&D maintains and operates, under a competitively procured contract, specialized track inspection research equipment. The contract also provides for related engineering services. Currently, the FRA Equipment Inventory includes T-6, the railroad research vehicle, the Gage Restraint Measurement (GRMS), the portable Ride Quality Measurement System (RQMS), and many other component parts.

The Office of R&D uses this equipment for data collection to support the agency's statutory safety mandate, and to provide a rational and effective basis for safety regulations and standards, and/or revisions, thereof. These activities include data collection and analyses relative to safe operation and ride quality of various high-speed trains being considered for operation in the US. Data collection to assess safety risks before granting waivers from FRA Safety Standards such as a waiver to operate above the currently allowed cant deficiency limit, is an important, ongoing activity.

As part of these efforts, instrumentation and data processing advancements uniquely applicable to the railroad environment have been developed. The most significant development has been the generation of a family of instrumented rail vehicles capable of measuring track geometry parameters against Federal Track Safety Standards at track speeds. Other developments have included portable data acquisition systems capable of measuring, calculating, and recording information, while calculating and displaying critical safety parameters such as lateral to vertical (L/V) force ratios in real time aboard the moving train.

FRA currently has one track research vehicle, the Instrumentation Vehicle (T-6). It is old, outmoded, and beyond its useful, economic life. The proposed project is to provide funding for its replacement with a single, state-of-the-art Track Research Inspection Platform (TRIP). It is envisioned that the proposed replacement would be designed as a multi-purpose and versatile TRIP, capable of replacing the GRMS Consist (T-6 & the hopper vehicle), and other previously-owned FRA research vehicles. It will also be capable of performing a wider range of testing with higher operational reliability and efficiency. Overall, cost analyses indicate that retiring the existing aged and outmoded research vehicles with a single, versatile state-of-the-art TRIP is the most cost-effective option to perform the envisioned work for the turn of the century, and beyond.

This project is to evaluate upgrading the T-6 with the acquisition of a new towed or self-propelled and self-contained FRA track inspection research platform. This proposed vehicle is to replace the only FRA-owned operational research vehicle (T-6), which serves as the instrumentation vehicle of the 2-vehicle GRMS consist. The other vehicle is a hopper on loan from the Union Pacific Railroad. In addition to GRMS and Track Geometry Measurement System (TGMS) capabilities, the intent is to design the vehicle for maximum flexibility so that it can serve as the test platform for research projects currently underway, such as the Automated Track Alignment System (ATDAS), Track Analyzer, Rail Head Defect Detection using EMATS, and similar future automated inspection research products, based on non-destructive evaluation

(NDE) technology. Validated inspection techniques could then be demonstrated to the industry for deployment, and to serve as a basis for updating FRA's Track Safety Standards. Results from the economic analysis and preliminary specifications for the envisioned TRIP vehicle are provided in this report.

Instrumented Wheelsets (IWS)

Several important vehicle track interaction problems require detailed wheel force data to predict critical track degradation patterns. In high-speed operations, track is required to be of the highest quality and to be held to fairly tight geometric standards. The effect of variations in geometry or the stiffness of the underlying track structure may be as important as the absolute magnitude of the irregularities. The next step is to identify specific maintenance procedures to reduce high or abnormal wheel rail forces, vehicle accelerations, and modes of response causing accelerated deterioration of either vehicles or track. The objective of the studies will be to eliminate safety hazards, reduce wear and fatigue mechanisms, and to minimize intrusive and de-stabilizing track maintenance activities.

Wheel/rail forces will be unique to each vehicle type and each operating situation, so the geometry and track structure must be optimized for the worst responding vehicle at any point. Of particular interest to high-speed rail are turnout negotiation, spiral to curve and spiral to tangent transition, and curve negotiation at high cant deficiency.

The detailed transition geometries of high-speed turnouts have been shown to greatly reduce wear and improve ride comfort. Further work on the switch geometry and detailed study of frog designs should advance this work. Studies analyzing concepts such as the flange supported frog, proper functioning of guard rails and the detailed geometry of moving point frogs would all greatly benefit from first quality wheel force data.

As with the turnout studies, the transition from tangent track to curves is an area of traditionally high forces and poor ride quality. Controlling the introduction of superelevation and the change of curvature may be smoothed to reduce wheel forces and transient accelerations. Wheel force data for some existing designs could help bracket the scope of these analyses. Further, this is a concern for both high-speed passenger operations as well as freight. Wheel force data tied to degradation models may expose areas of possible need for track realignments within existing rights-of-way or new performance-based safety standards.

Finally, high-speed rail operations sharing trackage rights with slower trains, whether freight or commuter, will typically operate at high cant deficiencies. Conversely, freight trains may consistently operate at speeds well under balance conditions. The implications of these extreme operations have been studied and safe operations can certainly be conducted. Wheel force data could, however, provide an important level of detailed sensitivities not currently available, which would lead to improving regulations.

Track Analyzer CLIM Box

The track analyzer system is under development by VNTSC and has been tested on T-6. The cross level index meter (CLIM) was developed in 1990 for FRA and several units are in the GFE inventory. The CLIM box is suited for a walking inspection of jointed track. The proposed new track safety standards include limits on repeated cross level anomalies which can lead to a rock-off derailment. A manual process for inspecting and identifying track likely to cause rock-off derailments is included in the proposed rule, however, installing the CLIM box on TRIP can make the process more effective and efficient. This effort can be expanded to evaluate the effects of cross level at intermediate and higher speeds.

Right-of-Way Digital Imaging Inspection System

A right-of-way digital imaging inspection system is not currently planned for design or installation on either the T-6 or T-10. A right-of-way digital imaging inspection system was developed in 1995, but not deployed. This was a basic digital imaging system to simply record images using a frame grabber to cover events recorded, while traversing the track structure from an inspection/research vehicle. It examines, in particular, road crossings, bridges, and track-safety standard exceptions.

The right-of-way digital imaging system required for inspection of turnout and special track components would differ greatly from the previously proposed system. The right-of-way digital imaging system would have the capability to capture and process images in order to align current images with stored images of either standard components, or more likely, images from that particular switch taken during previous inspection runs. By aligning and comparing the images, wear and damage may be detected and possibly measured. To inspect and determine wear and unsafe condition changes of turnout components will require greater image processing power and storage and recall of previous images of that specific component on the research vehicle. Progress in the power and speed of image processing equipment has been rapid and equipment is available off-the-shelf for most of the functions. Similarly, the cost of data storage devices has decreased, while the speed and capacity have increased, making this type of system more feasible now, than in the past several years. This appears to be a system worth incorporating into TRIP for track safety evaluation/application studies.

Vertical Track Stiffness

Vertical Track Stiffness (VTS) is a measure of the stiffness of the track as a vertical load is applied to the head of the rail. For light loads, i.e. less than 10 kips, most of the load is taken up in the track superstructure (rail, tie and fastener); but as the load is increased, the ballast and subgrade become more involved. Continuous VTS at a nominal low vertical load can give an indication of the tie/fastener condition. The more homogenous the VTS, the more uniform the support. At higher load levels, the VTS can be used to locate soft spots or anomalies in the ballast and subgrade. Current experimental systems use a seating load of 7 to 10 kips to evaluate superstructure stiffness and a load of 35 kips to get a reading of foundation stiffness. A key to interpreting VTS is to ensure that the light load and heavy load measurements are precisely superimposed. This is most easily accomplished when both loads are applied from the same vehicle during the same run.

Gage Restraint Measurement System

This measures how well ties and fasteners maintain gauge under load, at speeds up to 30 mph. The GRMS can quickly and efficiently locate weak-tie clusters that pose a high risk of a gage widening derailment. An unloaded gage of 56.5 inches is of little value if excessive gage widening is experienced under load. Maintenance personnel can reference the information developed in a GRMS survey while planning maintenance to prioritize repairs based on risk and economic factors. The gage-strength measurement data allow the track to be statistically segmented and allow curves, tangents, bridges, road crossings, etc. to be isolated for individual evaluation. The data can help answer questions such as: How strong is the track on a particular line segment? Where are the 10 worst locations on the line segment? How does the segment compare with other lines? Information like this can help maintenance officers make and back up, their decisions.

4. OBJECTIVES

This study examines the feasibility of the upgrade or replacement of the T-6 research vehicle and related requirements, specifications, and design. The upgraded/replacement research vehicle will be a platform containing all the requisite data acquisition, processing and analysis capabilities for measuring track performance characteristics from either onboard instrumentation or instrumentation from vehicles with which it is entrained or stationary from the wayside. It will also have the capability to communicate and collect data from other vehicles or wayside instrumentation, either through hardwire, via cellular modems, or both.

Each of the major systems will be studied to determine how the state-of-the-art components match the data requirements and how the feasibility of developing components match the requirements, if current technology falls short. Inertial track geometry systems are examined to determine if they fulfill research vehicle objectives better than contact systems, and whether more advanced technologies such as laser measurement systems may be the best fit. The feasibility study considers the risk of new system development versus the potential benefits of deployment in making recommendations. The ease with which a fallback position to a less risky technology is available, should developmental snags be encountered, is also taken into account in the recommendations.

The cost/benefit analysis considers various scenarios to assist in option selection that is most advantageous to the government. It includes the null option of not designing and building a new research vehicle as well as the options of leasing available vehicle with off-the-shelf technology, as opposed to fabricating the new vehicle.

5. VEHICLE SYSTEM REQUIREMENTS AND TRADEOFFS

The vehicle is defined as the vehicle body, including all support systems such as propulsion, braking and control systems, data acquisition and processing, instrumentation, communications, and crew quarters. All subsystems will meet or surpass the performance, environmental, safety, and other operational requirements of this section, and applicable standards and specifications listed in Appendix A.

5.1 VEHICLE CONFIGURATION

Based on the test requirement, the TRIP vehicle needs to be versatile and modularized. Test speed requirements can vary from 30 mph for GRMS measurements to 80 mph for instrumented wheelset measurements in the high-speed environment. To accommodate this range of speeds, the GRMS bogie has to be replaced with a normal bogie rated for high speed to perform instrumented wheelset tests. Another important design consideration is the load variability required for different tests. GRMS vertical load has to be in the range of 18 kips, while for vertical stiffness, two different loads are required; with the lighter load being less than 10 kips and the heavier load being up to 39 kips. Geometry measurements, preferably, should be recorded at the prevailing operating loads on a given line. If this is not possible, the heavier practical vehicle load should be used. Variable vertical load requirements necessitate the need for a vehicle with an extra axle in the center with abilities to change vertical loads. Versatile test requirements necessitate the need for a vehicle with an extra middle axle, having a modular capability to change a truck or an axle with minimal efforts, and vary the vertical loads.

The vehicle shall be capable of testing in either direction in a self-propelled configuration and/or towed configurations from zero to eighty miles per hour. FRA will select the optimal configuration based on FRA requirements and the costs associated with each option. Table 5.1 lists the advantages and disadvantages for a towed or self-propelled vehicle. However, this study will limit itself to the options of T-6 upgrade or the procurement of a new research vehicle.

Table 5.1 Descriptive Comparison of Alternative Propulsion Scenarios

Disadvantage	Advantages
Towed	
Damage in transporting the vehicle	Lower initial construction costs
Additional cost for locomotive power	Lower maintenance costs
Additional cost for railroad crews	
Delay due to railroad personnel schedules	
Self-propelled	
Higher maintenance cost of the propulsion system	Railroads will be more willing to allow testing due to less out-of-pocket costs
Additional labor cost for moving the vehicle	Lower operational costs
	Increase productivity due to self reliance
	Security of vehicle and equipment in transit

Vehicle Configuration

Possible configurations that will satisfy the need for a versatile research vehicle and that will be in the forefront of research and testing are discussed and evaluated in this section. Based on the versatility of the tests envisioned for this vehicle, two configurations are considered for discussion. One, upgrade the existing T-6, and two, construct a new vehicle to meet FRA's safety and research needs.

These configurations will have as a minimum, the requirements listed in this section, and will be able to test at 80 mph. The operating speeds are usually 30 mph for GRMS tests, restricted to timetable speeds or specified by the test engineer for other tests up to the maximum of 80 mph.

Mechanical Requirements

Trucks and Suspension:
The trucks and suspensions will be designed and constructed to comply with the speeds identified by the chosen option and operate safely on all U.S. trackage, as defined in Title 49.

Vehicle Weight Distribution:
The center of gravity location for the fully equipped vehicle shall not differ by more than the following amounts from the original "as built" vehicle (prior to equipment installation). The difference in the lateral direction shall not be greater than two inches. In the vertical direction, the center of gravity location shall not be higher than the original unmodified vehicle's center of gravity. The axle(s) closest to the track geometry sensors shall have a load of not less than 24 kips.

Maintainability:
All machinery and equipment shall be accessible through interior or exterior panels, hatches or covers. All routine maintenance and machinery removal shall be capable through these panels or hatches.

Wires and Lines:
All vehicle electrical cables, air hoses, and hydraulic lines shall be mounted in protective conduits and/or troughs. Capacity of conduits and/or troughs shall be sufficient for all wire, air hoses, and hydraulic lines necessary to support vehicle operations.

Fuel Capacity:
The vehicle must be capable of carrying enough fuel for a minimum range of 1000 miles in the self-propelled mode and provide for the auxiliary systems at the maximum speed for each selected option.

Water Capacity:
The vehicle must be capable of carrying at least 100 gallons of potable water to supply the sink and drinking fountain and a 50-gallon non-potable tank for the bathroom shower.

Crash Worthiness:
The vehicle must comply with applicable standards and specifications of Appendix A.

Environmental Requirements

Interior Noise Level:
At all speeds and with air-conditioning running, the noise level within the vehicle at any point, three to six feet above the floor and one foot from vertical surfaces, shall not exceed 76 dB.

Interior Heating, Air Conditioning, Ventilation:
The vehicle interior will be well insulated and will have an automatic, thermostat controlled, heating, ventilating, and air-conditioning system. The system shall be capable of maintaining a temperature in any part of the interior of 72 degrees Fahrenheit, ±5 F., given an outside temperature between -25 degrees F. to 115 degrees F. under conditions with at least 15 personal computers, six printers, and 15 persons.

Security

The vehicle must be equipped with a security system that will detect intrusion, turn on outside lighting, announce a warning message, and dial a preset telephone number to transmit a warning tone. The system must be easily armed and disarmed by those persons with appropriate security codes.

Clearance

The vehicle's dimensions must assure unrestricted operation. The vehicle must be in compliance with AAR Plate C.

Workmanship

The vehicle shall be free from defects such as incomplete welds, rust, cracks, or other defects that could impair its operation or serviceability.

Documentation

Maintenance manuals for all vehicle systems such as the electrical, propulsion, and braking systems shall be provided. Documentation shall also include wiring schematics, construction blueprints, system diagrams, and operator guides.

Train Control System

Equipment necessary for the operation at the speeds for the selected option shall be installed to comply with Title 49 and applicable railroad rules.

Reliability and Maintenance

Reliability:
The vehicle should be able to operate under impacts and vibration found in the railroad environment and extreme weather conditions.

Maintenance:
To reduce the spare parts required and facilitate maintainability, easily replaceable modules, with maximum commonality between modules, shall be utilized. The replacement of a single sensor package shall not require a cable replacement and vice versa. "Standard items" not provided, as spares shall be obtained only from manufacturer(s) offering field hardware maintenance. The manufacturer(s) shall guarantee to provide service anywhere in the continental United States within 24 hours of a request for service.

5.2 DATA ACQUISITION AND PROCESSING SYSTEMS

The system should consist of a Pentium based or higher computers, configured in an Ethernet network with two servers, two workstations, and a hub rated for a 100 Base-T or higher. The network will have the capacity to expand the number of workstations and printers by at least two. Two ports will be made available to interface with the network through the use of laptop computers. Test requirements established in the strategic plan and the need for real-time analysis and processing of large quantities of data, while controlling vital test operations, dictate this type of network at a minimum.

The system shall also be configured with at least two high-speed printers (one text, one strip chart), one laser printer, and one color laser printer for data output and printing. Storage of recorded data will be to computer hard disks and optical drives. Each of the two servers shall be equipped with a minimum of 10 G-bytes hard drive, one 3.5 floppy drive, and one read/write optical disk. The workstation computers shall be equipped with a minimum of 5 G-bytes disk drive, one 3.5 floppy drive, and one read/write optical disk.

Server and Workstation Requirements

Server:
The servers shall be in the instrumentation operator compartment and shall meet the following minimum of two each (dual) parallel processors - 300 MHz CPU or higher and state-of-the-art supporting peripherals.

Workstations:
Each workstation shall meet the following minimum requirements of one 300 MHz CPU or higher and state-of-the-art supporting peripherals.

Data Ports:
The network system shall have sufficient data ports for the devices specified below, A/D converters through which instrumentation data are sent to the computer, D/A converters to drive the oscillographs, and displays.

Optical Disk Drive:
The servers and each workstation shall include, at a minimum, at least one recordable CD (CD-R) drive with a minimum of 4X write transfer rate.

Data Terminal:
The network system shall provide 10 additional ports, either at the main server or any of the peripheral work stations, for data entry, or transferred to laptop computers or other information such as mileposts, track class, track type, track number, and track or wayside features, as required for a given test.

High Speed Printer:
Minimum speed of the high speed printer shall be 300 lines per minute at 120 characters per line and shall be coordinated with the other computer hardware and the software such that the printed events do not lag by more than 30 seconds during actual runs at the highest permissible track speeds.

Laser And Color Laser Printers:
The laser and color laser printers are network devices accessible by any of the computers on the network. The laser printer shall be a heavy-duty monochrome printer which will print at 600 dpi with resolution up to 800 dpi that will print at a minimum of 16 pages per minute and memory of at least 8 MB. The color laser shall have a minimum of 600 dpi, at a minimum of three pages per minute, with a minimum of 16 MB memory.

Monitors:
Each server and workstation computer shall be equipped with a 17-inch or higher diagonal high-resolution color or higher capability monitor.

Software

A minimum of two different operating systems, independent of the network, will be provided. Computer programs in general, shall be written in a language that is off-the-shelf, easily maintained, and compatible with existing routines used by other FRA inspection and research vehicles.

Signal conditioning

Filtering and amplification:
The system shall have 32 channels, expandable to 64, of signal conditioning and filtering. The output of these channels should be hardwired to the A/D converters on one server. The system

should have the capability to by-pass the amplification and filtering, and send a signal directly to the A/D converter.

Digital Inputs:
Four network ports will be made available to record/interface digital data from external recording and processing devices, and to provide geometry information to such systems from the vehicle geometry measurements.

5.3 ELECTRICAL POWER REQUIREMENTS

On-Board Electric Power:
A 100 kW minimum, 480V, 3-phase on-board power is required. The system shall have sufficient capacity, under all operating conditions, to power the systems described in this section, plus an additional 50 percent of that required. Power shall be compatible with wayside power sources that Amtrak passenger equipment uses on major railroads.

Electrical Outlets:
The TRIP shall have 110 VAC outlets, 12 VDC and 220 VAC electrical power on each wall of each room or area. A 110 VAC outlet with waterproof covers shall be provided on the exterior on each side of the vehicle, located at convenient locations for the instrumentation use. Each outlet shall be capable of providing 15 amperes of 58-62 Hz 112-117 V.

Isolated Electrical Grounded Outlets:
The TRIP shall have 110 VAC isolated grounded outlets for the computer and other sensitive equipment. These outlets will be orange in color and located in the instrumentation room, the conference room, and at outside data junction boxes.

Emergency/Standby Power:
The system shall have emergency/standby power capability and must switch over automatically upon generator failure. This system should be designed to provide sufficient power to the data acquisition system for recovery or safe shutdown.

Power Surge Protection:
Power surge protection and backup power will be made available for six ground isolated independent computer circuits. This should provide sufficient power for the computer to shutdown without losing any data.

5.4 COMMUNICATIONS

Train Radio:
The train radio mounting system shall be an AAR standard locomotive standard 97-channel system. One radio shall be mounted at the vehicle controls at each end of the vehicle.

Cellular Telephone:
One cellular phone for voice transmission shall be mounted in the kitchen area.

Facsimile Cellular System:
The vehicle shall have a facsimile (FAX) cellular system with at least a 54 KBPS cellular modem in the instrumentation area. The FAX system shall also include capability for plain-page printing and copying. Scanning and transmission shall exceed six seconds per page. The system may be a combined unit or a PC-based computer with scanner and FAX software. The FAX cellular system shall be separate from the cellular telephone and will not interfere with voice communication while the system is transmitting or receiving a FAX.

Satellite Data Transmission/Reception:
A system shall be installed where Electronic Mail messages may be received and transmitted under high priority. Hardware shall be installed for connection with a commercial service via a satellite to provide FRA with two-way E-mail message ability to the TRIP at any location, except for tunnels or other natural or man-made conditions which may block satellite transmission, for the reception and transmission of E-mail to/from FRA's Internet E-mail addresses.

Intercom:
The intercom system shall provide talk/listen capability between the operators' consoles, the observation area, and the kitchen. An exterior intercom jack shall also be provided on each side of the vehicle within six feet of any instrumentation, and at the forward and rear operator's positions.

Head Sets:
Two headsets with four 50 feet extension cords to be plugged to the outside jack for working on adjacent vehicles and on the instrumentation loading systems.

Backup System:
A redundant audio (buzzer system) and visual (red light) for communication between the vehicle operator and rear observation space shall be installed.

5.5 INSTRUMENTATION

Basic Instrumentation:
Basic instrumentation for the TRIP vehicle will include the TGMS, GPS and the Right-Of-Way Digital Imaging Inspection System. In addition, four data connection locations will be provided throughout the outside of the vehicle for connecting test dependent instruments with the data acquisition system. Since this is a test research platform, the majority of the instrumentation equipment required such tests as GRMS, IWS, VTS etc. will be provided and attached to the vehicle based on the test to be conducted.

Data Connections:
The data connections on the vehicle will be located at each end and on each side of the vehicle. Each of the four locations will have, as a minimum, 16 – 8 pin data cables and connectors, one network connection port, one Digital Imaging port and an intercom line.

5.6 CREW ACCOMMODATIONS

Layout

Floor Space:
The vehicle shall have a minimum of 750-800 square feet of space available for the instrumentation, data processing hardware, controls, data displays, and interior facilities.

Kitchen Space:
The kitchen shall be equipped with a two-burner electric stove, a microwave oven, a refrigerator, a sink with hot and cold running water, a storage cabinet, a table, and seating for six persons.

Bathroom:
A bathroom shall be provided, equipped with a storage cabinet, lavatory, shower, and chemical toilet capable of accommodating a maximum of 10 persons daily. If the toilet uses compressed air, it shall not affect the safe operation of the train brake system. The toilet must have a clean-out and recharge-type system. An incinerator-type toilet system shall not be used. The bathroom shall have a small shower.

Sleeping Quarters:
Private sleeping accommodations shall be provided for two persons. It shall have an electric outlet. In addition, two emergency sleeping bunks shall be provided. It shall be of the folding type that converts from bed to seat configurations.

Workshop:
A workshop shall be provided, equipped with workbench and storage facilities for tools. The storage facilities shall have a keyed lock.

Closet:
Space shall be provided to accommodate clothing, suitcases, and briefcases for 10 people. This space shall be equipped with coat hooks, clothes hangers, and shelves.

Storage Space:
Separate storage space for storing recommended spare parts shall be provided for the following consumables: Oscillograph supplies for 20 operating days, computer supplies for 40 operating days, and instrumentation lubrication and supplies for 20 operating days: Vehicle lubricants and miscellaneous supplies for 10 operating days; and hotel supplies for 10 operating days.

Drinking Fountain:
A drinking fountain shall be provided to supply sufficient cooled fresh drinking water for 10 people daily for three days using potable water.

Office/Operator's Compartment:
A compartment shall be provided with desks, cabinets, and chairs to be used as a conference room or office space.

Instrumentation Space:
An instrument space, easily accessible from both ends, shall be located in the middle of the vehicle. At a minimum, the space shall be 100 square feet of which approximately 40 square feet shall be available for the mounting of equipment. The space shall be equipped with a false floor or other arrangement such that electrical wiring and cabling used for the measurement systems and the vehicle shall be below floor level and will not present a tripping hazard. Access to the wiring shall be by ordinary hand tools.

Lighting

Exterior Lights and Cab Lights:
The vehicle shall be equipped with headlights, classification lights, marker lights, emergency lights, and visibility and cab lights that comply with applicable standards, Appendix A.

Instrumentation Lights:
Lights shall be mounted underneath the vehicle to provide illuminating for instrumentation/load application systems. Controls for these lights shall be located in the instrumentation/load space and at the operating council. The light shall be protected against breakage from objects thrown up from the track.

Exterior Lights to Illuminate Rails:
Two 100,000 candela (minimum) sealed beam rear lights shall be installed on the rear of the vehicle to illuminate the two rails. The lights shall be protected against breakage from objects thrown up from the rails. The lights shall be controlled in the observation space.

Interior Lights:
The vehicle shall be equipped with interior lights for both daytime and nighttime operation. The lighting system shall be capable of providing 34-foot candles for reading illumination for personnel onboard the TRIP. The illumination at floor level shall be at least 15 feet within its respective space. Appropriate emergency lighting shall be installed.

Safety

Moveable Items:
All moveable items such as tools, instruments, and chairs shall have a storage compartment or space with positive mechanical tie-downs, or locking doors or drawers.

Wires and Lines:
The vehicle shall provide for protective and accessible conduits and/or troughs. Capacity of conduits and/or troughs shall be sufficient for all wire, air hoses and hydraulic lines necessary to support the vehicle requirements.

Vandal Resistance:
All interior and exterior access shall be vandal-resistant. The vehicle shall have exterior fuel cut-outs with covers.

Windows:
All windows must meet the requirements of Title 49. Side windows shall be tinted to reduce air-conditioning requirements.

Emergency Lights:
The vehicle shall be equipped with emergency lights in the instrumentation compartment and near each of the vehicle doors.

Exposed Edges:
The interior and exterior surfaces shall not have exposed edges that present a hazard to personnel.

Drawers, Hatches, and Door:
All drawers, hatches, and doors shall have positive latches. The vehicle must have top hinges only on all exterior accessory doors.

Flammable Consumables:
No liquid or gas consumables more flammable than No. 1 or No. 2 diesel fuel shall be used aboard the vehicle.

Safety Items or Safety Item Holders:
All safety items or appliances, except for handholds, shall be painted red and mounted in conspicuous places, and will be clearly labeled as appropriate.

Exits:
All vehicle exits shall be marked in red letters, at least 2 inches high.

Steps:
All steps or rises 1/4 inch or more shall he painted yellow and marked CAUTION-STEP.

6. PLATFORM CAPABILITIES AND MEASUREMENTS

The basic TRIP vehicle will have, as a minimum, proven inspection/testing capabilities and technologies given in Table 6.1. These inspection technologies are used in one form or another throughout the railroad industry to determine the reliability and safety of the track structure to carry the current loadings. Other than TGMS, which is covered by current FRA regulations, the other technologies are used on a waiver basis. TRIP will provide and collaborate existing data to develop performance-based regulation/standards and evaluate their applicability in the railroad environment.

Table 6.1 Minimum Requirement for TRIP Track and Structure Inspection Technologies

Proven Technologies Incorporated on the Vehicle	Comments
GRMS	Gage Restraint Measurement System
TGMS	Automated Track Geometry Measurement Systems compatible to T-10 or its replacement.
GPS	The Global Positioning System will assist in the data reduction and vehicle operation. Further it can be used to evaluate available coverage for various positive train separation (PTS) scenarios currently under development by the railroad industry.
Instrument Wheel Sets	Evaluate the safety implication under various operating conditions of the vehicle/track interaction of new and untried track structure or vehicle concepts.
Rail Profile	Optical or laser rail profiling such as used on railroad track inspection vehicles to ascertain rail head loss.
Right-of-way Digital Imaging Inspection System	Digital Imaging cameras combined with image processing software to evaluate broken or missing track components.

Additional TRIP Capabilities

Additional TRIP capabilities given in Table 6.2 are designed to accelerate the development of performance-based safety standards in these areas. Research has been performed in all the areas listed in Table 6.2, either by FRA, its contractors, or the railroad industry. Having a platform where the most promising technologies can be evaluated under operating conditions will accelerate the implementation of optimal inspection technologies and provide a facility to evaluate new inspection technologies as they become available.

Table 6.2 Additional TRIP Research and Inspection Capabilities

Potential Technologies to be Incorporated on the Vehicle	Comments
Track Analyzer / CLIM Box	Predicts tendency for unsafe vehicle/track interaction such as harmonic rock-off derailment. The Cross Level Index Measurement system is a counterpart of the Track Analyzer for walking inspection of track.
Vertical Stiffness	A system is under development for T-6 to measure the vertical stiffness of the track-ballast-subgrade combination.
Subgrade Assessment	Subgrade penetrating radar and geophysical techniques may be applicable to detect or investigate areas of inadequate subgrade strength or the existence of water pockets or other embedded objects.
Vehicle Ride Quality and Vibration Measuring System	Systems are under development to detect and warn of hazardous vehicle motion. Candidate systems can be correlated with track geometry condition measured by TRIP to evaluate the reliability of the system and correlate with track condition that causes the problem.

7. ECONOMIC ANALYSIS

Options Considered

A number of options have been considered in this economic analysis. Options that were considered but eliminated from further analysis included: 1) obtaining field testing services from other research organizations, 2) eliminating the research programs requiring a track research vehicle and 3) maintaining the status quo. The first option was eliminated due to the lack of available versatile track research vehicle(s) that would be able to meet all of FRA's current safety and track research needs listed in Section 6. The second option compromises FRA's basic mission, which is to ensure a safe operating environment for the railroad system. The third option is an expensive proposition, as described later in this section. In addition, this option is deemed marginal at best with respect to the requirements of track research goals identified in the FRA R&D Five-Year Strategic Plan. Indeed, the key factor for the further consideration of an option in this economic analysis was its responsiveness to the goals of the strategic plan. Only two options satisfied this key criterion, namely, the upgrade of the T-6 or the replacement with a new vehicle. The benefits and costs associated with each of these two options are discussed below.

Benefits Associated with Upgrade or Replacement of the T-6 Track Research Vehicle

There are four primary factors which are accountable for savings as a direct result of the acquisition of a new TRIP vehicle. These factors of potential significance are Track Inspection Research Support, FRA's Office of Safety Technical Support, Operational Efficiencies, and Research Delays. The estimated savings are at $550,000 annually, and the basis, therefore, for each of these factors, is discussed below and summarized in Table 7.3.

Track Inspection Research Support

The TRIP will serve as a laboratory on wheels to validate various advanced track inspection technology projects and collect data for the development of various software and hardware prototypes and models. Lack of such a vehicle would significantly increase the cost of these track research projects. Illustrated here are two projects currently in progress and requiring such support. Currently, track data is collected annually from some designated track segments, totaling about 500 miles, using FRA's GRMS consist under the cooperative gage strength survey program. Another important project the new TRIP would support is the advanced application of EMATs in rail inspection. Recent results appear to be encouraging in detecting internal rail flaws hidden by surface conditions such as head checks, shelling, and dirt. Following the completion of the prototype development work, extensive support would be required for field tests to evaluate its performance. Total annual savings resulting from the efficient accomplishment of these and other research support activities, once a new TRIP is available, is estimated at about $150,000.

FRA's Office of Safety Technical Support

Based on GRMS testing, a proposed new track safety standard will provide information on railroad crossties and rail fastener requirements. A new state-of-the-art research vehicle with GRMS capability would foster standardization of the application of this new technology, and would be available to the FRA's Office of Safety for the training of track safety inspectors, as required. The vehicle could also be used as a performance yard stick for other GRMS systems developed by the railroad industry. Further, the vehicle could aid in the full implementation and future revisions of safety standards. Estimated savings from this effort are about $50,000.

Operational Efficiencies

The aged T-6 vehicle, supporting the GRMS consist, is in need of refurbishing and updating to maintain minimum reliability and performance. Considering its age of 48 years (1950), full safety inspection and expensive repairs are necessary. Other refurbishing work and performance enhancements will require significant capital outlays not included in this analysis, which is limited to annual savings only. Based on T-6's cost history, the annual maintenance costs of the existing GRMS consist is estimated at $150,000. The corresponding routine maintenance cost of the new research vehicle would be only about $50,000, for a potential estimated annual savings of $100,000.

The T-6, in the GRMS consist, is operated by a standard crew of three when in a testing mode. The proposed new research vehicle would require only a crew of two to operate at an estimated labor cost savings of about $50,000 per year. This does not include the standard three-person railroad crew required to operate the consist. This estimate is based on the average activity level and crew cost of the GRMS consist for the past three years. The savings will be even more significant when the full testing capabilities envisioned for the proposed TRIP are taken into account. An additional annual savings of $25,000, as a minimum, can be safely assumed when the additional testing capabilities are utilized.

Due to age-related breakdowns and associated repairs of the T-6 at least ten (10) days of scheduled testing are lost annually. The cost of these productivity losses is estimated at $5,000 per day or about $50,000 per year. The corresponding cost to the cooperating railroads, in terms of test locomotive, operating crew, and other test support, is at least equal to this amount, $50,000. Therefore, the potential productivity gain as a direct result of a new TRIP is estimated at $100,000.

Based on the above analyses, the estimated annual savings because of expected operational efficiencies and increased productivity would be about $275,000.

Research delays

Costly delays on various research projects will be encountered based on T-6's condition or a lack of a new research vehicle. Rescheduling of tests, establishing new techniques to obtained data, and delays in deliverables affecting other projects are impacted by the T-6 research vehicle. A conservative estimate for this cost, based on test day and productivity losses at $5,000 per test day, is $75,000.

A summary of these estimated annual savings are given in Table 7.1.

Table 7.1 Estimated Annual Savings

Cost Saving Categories	Estimated Savings
Research Support	$150,000
Technical Support	$50,000
Operational Efficiencies	$275,000
Research Delays	$75,000
Total	$550,000

Costs Associated with Upgrade or Replacement of the T-6 Track Research Vehicle

Based on all possible options considered that would meet FRA's research requirements, two were chosen for further consideration. These were the T-6 upgrade or a new research vehicle, either towed or self-propelled. The costs for each option are given in Table 7.2. Included in the table are the initial construction or upgrade costs, the annual operating costs, and the total costs for a five-year window.

As a bench mark, costs for comparison purposes only from two other inspection vehicles using GRMS technology are given. These are Union Pacific's EC-4, GRMS and track geometry vehicle at approximately $5.7 million, and Conrail's GRMS system at approximately $2.0 million. As seen from Table 7.2, the construction costs for T-6 upgrade or a new vehicle are within this range.

An additional cost, not included in Table 7.2, is track research vehicle usage loss for approximately one year during the upgrade processes. Based on 1997 usage of 90 testing days and $5,000 per test day, a total cost of $450,000 would have been required to support current research efforts. This can be considered an additional rental fee cost for a research vehicle, if one were available. Table 7.3 gives the primary cost categories for three options: upgrade, replacement with a towed vehicle, or replacement with a self-propelled vehicle. Included in these categories are construction, usage, annual operation costs and costs for a five-year window.

Table 7.2 Construction and Operational Costs for Upgrade or Replacement of FRA's T-6 Track Research Vehicle

Sub-Systems	Upgrade	Replacement	
		Towed	Self-Propelled
Construction Costs			
Vehicle	$1,250,000	$1,500,000	$1,500,000
Propulsion System 80 MPH			$250,000
Data Acquisition	$31,000	$31,000	$31,000
Signal Conditioning	$128,000	$128,000	$128,000
Data and Communication Cabling	$150,000	$125,000	$125,000
GRMS – Truck	$500,000	$500,000	$500,000
Hydraulic Power Pack for GRMS	$70,000	$70,000	$70,000
Video Inspection System	$22,000	$22,000	$22,000
Geometry Measurement System	$280,000	$280,000	$280,000
Rail Profile	$150,000	$150,000	$150,000
Communication System	$3,500	$3,500	$3,500
GPS – System	$25,000	$25,000	$25,000
Total TRIP Construction Costs			
Total Construction Costs	$2,609,500	$2,834,500	$3,084,500
Operational Costs			
Operational / Movement Costs	$58,000	$58,000	$41,000
Testing Costs @ 200 Miles Test -	$12,000	$8,000	$8,000
Annual Maintenance Costs	$25,000	$25,000	$35,000
Total Annual Operational Costs			
Annual Operational Costs	$95,000	$91,000	$84,000
Total Construction and Operational Costs for Five Years			
Total Vehicle Cost for Five-Year Window	$3,084,500	$3,289,500	$3,504,500

Table 7.3 Cost Summary for Upgrade or Replacement of FRA's T-6 Track Research Vehicle

Primary Cost Categories	Upgrade	Replacement	
		Towed	*Self-Propelled*
Construction/Upgrade Costs	$2,609,500	$2,834,500	$3,084,500
Usage Loss of the Research Vehicle	$450,000		
Operational Costs (Five Years)	475,000	455,000	420,000
Total Costs for Five-Year Window	$3,534,500	$3,289,500	$3,504,500

8. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In order to meet the track safety R&D goals delineated in the Five-Year Strategic Plan, a T-6 "upgrade" or "replacement" with a new state-of-the-art vehicle is necessary. In addition to meeting this key program, this "upgrade" or "replacement" would result in a significantly more cost-effective track safety R&D. The analysis of the available data indicates that the proposed investment in a new TRIP will be recovered in approximately five years, considering only the above estimated annual savings. Other important considerations, in terms of real benefits, but more difficult to quantify, include improved data quality from the new TRIP, its use as a laboratory on wheels for various research capabilities listed in section 6, and the advances in the state-of-the-art of track safety inspection. Taking these factors into account in the above analysis would make the proposed TRIP an even more attractive investment from an operational effectiveness point of view, and imperative from a programmatic point of view, to meet the envisioned minimum FRA mission requirements at the turn of the century, and beyond.

Recommendations

Replacing the aging T-6 vehicle with a new state-of-the-art vehicle will significantly enhance FRA's track R&D capability and at the same time significantly improve the cost-effectiveness of R&D implementation, and will ultimately improve railroad safety and increase its economy of operation. It is therefore recommended that a completely new vehicle be constructed for its operational versatility in the railroad environment and flexibility for future research/inspection development needs. Further, the loss of a research vehicle during the upgrade of the T-6 will delay other research projects that are currently included in FRA's research mandate. From the cost point of view selecting, the replacement option is more economical when all direct and indirect costs discussed in the previous section are considered.

The need for a vehicle to be able to move to a test site and out again in minimal increments of time is of the utmost importance. The first question asked by railroad personnel when test time is requested is "How long will you occupy the track?" The ability to move onto the track, perform the test, and move out in a minimal increment of time will make it easier to obtain track testing time. In addition, eliminating the need for a crew, other than a pilot, and a locomotive, in a time of scarce industry resources, will speed up preparations and test time, thus reducing costs.

Selection of the option of a new replacement vehicle over the T-6 upgrade is based on their comparative technical capabilities. The versatility of having an independent vertical (and possibly lateral) load arrangement that can be independently controlled would outweigh additional costs, in the range of one-half of one million, which is not the case here. Based on the budgetary estimates indicated above, their costs are comparable. This versatility will allow the development of vertical track stiffness from a moving vehicle without having to make two runs over the same track. The reliability of the data will be unquestionable. Also, having to make one run, from just one of the many test capabilities this vehicle will have, over a given test section, will increase productivity substantially and recover some of the initial investment, which were not taken into account in the conservative estimate of five years, for capital recovery previously indicated.

Table 8.1 below summarizes the major obstacles for upgrade option and the advantages for the replacement option. A new clean design has the advantage over the modification of the old T-6 instrumentation vehicle. Costs for this items where possible were considered in the analysis, however, there could be some additional costs due to the structural integrity of the T-6. During many years of service, the T-6 has been damaged in transport and derailments. The extent of the structural damage cannot be confirmed until the car has been disassembled.

Table 8.1 List of Major Obstacles and Advantages Considered for FRA's Research Needs

Upgrade	Replacement
Vehicle built in 1953 and last modified in 1976	Provides clean under frame to incorporate vertical or lateral load fixtures
Spare parts are a problem leading to higher annual maintenance costs	Decrease in annual operating costs
Costly asbestos abatement (not included in the budget until a thorough inspection of the vehicle is performed)	Design and incorporate versatility platform for testing future technologies
Existing vehicle configuration will interfere with instrumentation and loading requirements	Spare parts readily available

A new instrumentation platform with future capabilities of applying a controlled vertical (and possibly lateral) load at any location along the track, while recording all geometry parameters, and providing instrumentation and computer analysis capabilities, will enhance the abilities of the FRA to fulfill its mission to ensure the safety of the railroad system.

APPENDIX A

APPLICABLE STANDARDS AND SPECIFICATIONS

The following reference documents and manuals will be incorporated for use in the design, manufacture, and performance testing of the instrumentation platform vehicle, described herein. Where standards or specifications appear to overlap, the most restrictive will prevail. All reference documents used will be the most current published, including revision pages at the time of contract award. A copy of the applicable standards will be made available and attached to the vehicle and instrumentation operating manuals.

Standards

1. Code of Federal Regulations, Title 49, Transportation.
(Note: 49 CFR Part 216, Passenger Equipment Safety Standards, Notice of Proposed Rulemaking (NPRM), Federal Register, 9/23/97, shall be followed if the Final Rule has not been promulgated; and Note: 49 CFR Part 213, Track Safety Standards, NPRM, Federal Register, 7/3/97, shall be followed if the Final Rule has not been promulgated.)

2. Code of Federal Regulations, Title 40 Environmental Protection Agency.

3. Code of Federal Regulations, Title 29 Occupational and Health Administration.

4. Association of American Railroads (AAR, Manual of Recommended Standards and Practices and the Field Manual of Rules of Interchange).

5. American Society of Testing Materials (ASTM manuals).

6. National Electrical Code (NEC) Manual.

7. International Standards Organizations (ISO) Manuals of Standards.

8. American Welding Society (AWS) Manuals.

Specifications

1. Mil-C-22992 Electrical Connections.

2. EIA-RS-284-Electronic Industry Association Wire Wrap Specifications.