Testimony

Of

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Before the

United States Senate
Committee on Commerce, Science, and Transportation
Subcommittee on Surface Transportation
and Merchant Marine

May 9, 2001

9:30 AM
SR-253

Infrastructure Investment Needs of United States Railroads

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Mr. Chairman and Members of the Committee:

I am pleased to have the opportunity to speak to you today on the subject of infrastructure investment need for US railroads.

My name is Dr. Allan M. Zarembski and I am president of ZETA-TECH Associates, Inc., a technical consulting and applied technology company specializing in the railway industry. I have over 25 years of professional experience in the railway industry and have expertise in the areas of track and track component behavior and failure, degradation analysis, railway operations, maintenance, and the dynamic interaction between railway vehicles and the track structure. I am the former Manager of Track Research of the Association of American Railroads where I directed the railroad industry's research program in the area of track and structures, as well as former Director Research & Development for several major railroad industry suppliers. I have been president of ZETA-TECH Associates, Inc. since 1984 when I founded the company. I have a Ph.D. and MS in Civil Engineering from Princeton University and a Masters and Bachelor degree in engineering from New York University. I am registered as a Professional Engineer in five states. I am the author of over 90 technical publications and an additional 130 published articles, all in the area of railroad engineering. I am author of the book Tracking R&D; Research & Development and was the recipient of the 1992 Rail Transportation Award of the American Society of Mechanical Engineers. I am a Fellow of the American Society of Mechanical Engineers. My complete CV and list of publications is attached to this testimony.

One of my specific areas of expertise is the degradation and failure of the railroad track structure and its key components. I have been a leader in the analysis of the life of the key railroad track components and in the development of maintenance management and planning tools for the prediction of railroad capital and maintenance needs. ZETA-TECH has developed and implemented maintenance planning models for railroads since the late 1980s and our models have been applied on virtually all of the major US and Canadian railways as well as numerous railways overseas. Our methodology for assigning the costs of maintaining a shared right-of-way to the various users (accepted by the Interstate Commerce Commission in 1995) has been applied extensively in North America and Europe.

My purpose today is to discuss two separate studies which examine the investment needs of the U.S. railroad industry for maintenance of their infrastructure.

I. Executive Summary

Last year, ZETA-TECH undertook a study for the American Short Line and Regional Railroad Association (ASLRRA) to determine what was the capital requirements needed by the approximately 550 short line and regional railroads to allow them to operate the new generation heavy axle load railways cars safely and cost-effectively on an ongoing, long term basis. This study was partially funded by the Federal Railroad Administration through a cooperative agreement with the American Short Line and Regional Railroad Association. While the current level of track and structures is generally adequate for traditional railroad cars that weigh up to 263,000 pounds (and have 33 ton axle loads), is it often inadequate and potentially even unsafe for the new generation 286,000 pound cars with 36 ton axle loads. This 9% increase in load can translate into damage to the track structure that is as much as 20% higher than that caused by the "standard" 263,000 pound car. This has led to concerns by the short line and regional railroads about the ability of their current infrastructure to effectively handle this new traffic. These railroads are also concerned about the potential cost of upgrading their fixed plant (track and bridges) to handle cars of this weight on a long term business basis.

ZETA-TECH developed a model that took account of traffic volume and operating speed in determining where major component renewals might be required on the 50,000 track miles operated by short line and regional railroads. Our conclusion, which I presented in testimony before the House Ground Transportation Subcommittee of the Transportation Committee earlier this year, was that an investment of $6.86 billion would be required in track and bridges if all short lines were to be able to safely handle 286,000 lb. cars.

In a separate study that we are currently conducting for the Association of American Railroads, ZETA-TECH is determining the capital investment needs of Class I railroads in the United States[1]. This analysis looks at capital investment in track, bridges, and signals, and also quantifies maintenance of way expenses (the non-capitalized portion of track maintenance). The purpose of the analysis is to identify a "steady state" level of spending. This is defined as the constant level of investment required to maintain the existing fixed plant in its present condition.

For Class I railroads, this represents a track condition that has already been upgraded to handle the new generation 286,000 lb. heavy cars on most main and secondary lines. Furthermore, this upgraded level of track condition is significantly better than it had been in the 1970's and 1980's.

Looking at the distribution of traffic, track condition, and topography, ZETA-TECH utilized its engineering based analysis models to calculate the Class I railroads' required annual level of capital investment. It also calculated the corresponding level of infrastructure maintenance required. Preliminary results indicate that the steady state

[1] This is a regulatory classification, for railroads having more than $258.5 million in revenues in 1999.

level of spending required by Class I railroads, exclusive of short lines and regional railroads, is of the order of $8 billion per year for track, bridges and signals. This includes both capital and maintenance expenditures.

II. Determining Investment Needs Using Engineering Based Models

The U.S. Class I railroads operate and maintain more than 168,000 miles of track (this figure includes main and branch lines as well as yard and industry trackage). Short line and regional railroads (regulatory Class II and Class III companies) own and maintain about 50,000 track miles. Total network size is thus about 218,000 miles. All of this track must be maintained in safe operating condition.

The major components of the railroad's infrastructure consist of the track structure itself, which includes the rails, ties, ballast, and special trackwork. Also included are the bridges, signals, and structures. Many of these major components of the infrastructure are subject to wear and tear under railroad operations, specifically the passage of the railway cars over the track. This includes all of the major track components.

On the higher density main and secondary lines, these track components will 'wear out' after the passage of millions of tons of train traffic and require replacement. This replacement is performed independently for these track components at the end of each component's useful life.

The lives of the major track components are determined primarily by the volume of traffic, secondarily by factors such as axle loads, operating speed, curvature and grade, and environment. To remain in business, railroads must replace these components at least as fast as they wear out. There is a good indication that railroads are doing this in the safety statistics published by the Federal Railroad Administration. Track related railroad accident rates have been declining for more than ten years. This is due in part to the generally good condition of the fixed plant on the Class I railroads. The fixed plant today is certainly in better condition than it was in the 1970's and 1980's.

The relationship between traffic volume and the mechanisms that determine the life of track components (wear and fatigue for rail, mechanical deterioration and environmental decay for ties, and the same for ballast/surfacing) can be quantified. It is possible to construct models that will calculate the life of track components if information can be provided on traffic volume and other track and traffic characteristics such as speed and axle load, curvature, and the type, age, and condition of track components.

ZETA-TECH has constructed such models, and has successfully applied them for railroads both in the United States and abroad. Since these models calculate the life of track components, they can also be used to determine the quantities of components that must be replaced each year. By application of appropriate unit costs, the size of the annual investment required to maintain a railroad in its present condition may be calculated.

III. Class I "Steady State" Infrastructure Needs

Railroad investments in track components (especially rail and ties) are long-term investments. Surfacing may be required every one to ten years (depending on such factors as climate, volume of traffic, and ballast and subgrade conditions), ties last 10 to 40 years (or more, in dry climates on tracks with low traffic), and rail can last as long as a century on light-density lines.

The long lives of track components make determination of steady state requirements difficult. External factors in the past, such as periods of boom traffic, have produced periods of heavy investment in track assets. Amounts spent in any given year will depend upon:

- Past investments
- Current traffic volumes
- Business conditions
- Traffic expectation

Fortunately, when the entire Class I industry is considered as a single network, these cycles tend to even out. Selection of a long enough time series of data enables an analyst to at least approach an estimate of steady state spending. In addition, engineering based component life models allow for a more accurate assessment of specific component lives and corresponding maintenance cycles. Applying these component life models to a large network allows for an accurate analysis of long term capital needs.

As an example of the use of engineering models for determining capital needs, ZETA-TECH developed a Capital Allocation Model. As its name indicates, it is intended to tell a railroad what quantities of components must be replaced each year, on a steady state basis, and the associated capital budget required by the railroad to maintain its infrastructure investment. Such a model makes use of known component life relationships between such key factors as traffic density, track structure, and topography (e.g. curvature). These component life relationships were developed using ZETA-TECH engineering equations and railroad performance data, and they address the key track components of rails, ties, ballast, and special trackwork (turnouts, switches, crossings).

The Capital Allocation Model was originally developed to provide a railroad with a neutral and scientific method of programming track capital renewals for rail, ties, and ballast/surfacing. To do this, the model had to properly account for the physical and environmental characteristics that determined track component degradation. For each of the major component categories (rail, ties, ballast, special trackwork) the model incorporates a relationship between traffic density and environment, that allows the model to predict component life in years and the required date of replacement. In addition to the density/environment relationship, the model also addresses other key track and geographic parameters such as curvature, a very important determinant of rail life.

The model's mechanism for prediction is to take the component lives (in MGT), developed within the model, to obtain an expected life on each segment for each combination of traffic density and curvature. The relationship between rail life and tonnage is linear, since general practice in the rail industry is to express rail life interchangeably in either cumulative tonnage or years. However, annual tonnage on many segments is low enough to produce improbably long lives for rail. At some point, rail must be replaced due to technological obsolescence or environmental decay (rust and corrosion) even if no traffic uses a rail line. The Capital Allocation Model uses an 80-year maximum life for rail, based on ZETA-TECH and industry experience.

For turnouts, a similar relationship is used. However, maximum life of turnouts in main track is set at only 10 years, due to the rapid accumulation of damage from the passage of heavy axle load traffic. For ties and ballast, relationships can be nonlinear, particularly at lower traffic densities. This is due to the substitution of traffic damage for environmental decay as traffic increases. Again, however, a maximum life in years is established, due to the effects of environment on low-tonnage lines.

The model then uses the above component life relationships and costs to predict, for each segment in the database, a life for each of the component categories (rail, ties, ballast/surfacing, and turnouts). Using these lives, and standard unit costs the model produces the following:

- Steady state renewal requirements for each component (in units)
- Steady state capital budget requirements (in $), by component, category
- A total capital cost for steady state track component renewal

For the Association of American Railroads, ZETA-TECH applied its Capital Allocation Model to a database of all Class I railroad track in the United States to determine the capital investment required to maintain the fixed plant in its present condition. The network database used was that of the U.S. Class I railroad industry prepared by the Volpe National Transportation Center at Cambridge, MA. This model consists of more than 8,000 line segments.

ZETA-TECH used engineering model based track component lives for new rail, secondhand or "relay" rail, ties, and ballast/surfacing in modeling required capital investment. Engineering models such as ZETA-TECH's capital expenditure model predict component renewals that *should* be needed, taking into account annual tonnage and track geometry. Actual trackwork performed will vary from year to year, due to factors previously mentioned: traffic volume, the financial health of the industry, and the age distribution of rail and turnouts already in track. Therefore, statistics on historical renewal rates have been used to calibrate the ZETA-TECH model's predictions.

The product of ZETA-TECH's model application to the database of track segments making up the Class I railroad industry is an estimate of the component replacement requirements necessary to maintain the network in its present condition.

In addition, supplemental analyses were performed to determine the maintenance of way expenses, i.e. the non-capitalized portion of track maintenance, as well as the capital costs associated with bridges, signal systems, and other related infrastructure components. In the case of the maintenance of way operating expenses, these analyses examined the relationship between these expenses and such key parameters as miles of track and ton-miles of traffic carried. As with the capital investment analysis, the focus was on defining the level of outlays necessary to maintain the railroad's infrastructure in the condition it is in today.

This analysis, which is not yet complete, will provide an estimate of the "steady state" infrastructure investment requirements of the Class I railroad network. Preliminary results indicate the following:

- Replacements of rail, ties, ballast, and turnouts, and performance of miscellaneous related activities such as rail grinding and welding, were estimated to require $2.7 billion annually
- Estimated expenditures on bridges and signals add another $500 million
- Maintenance of way operating expenses represent an annual cost of approximately $4.5 billion.
- ZETA-TECH estimates that a total approaching $8 billion annually, or about $46,000 per track mile, must be spent annually to maintain Class I railroads in their current condition.

The total does not include funds spent on additional passing sidings, double track, or other measures to increase capacity.

IV. Upgrading Short Line Infrastructure for Heavy Axle Loads

In order to take advantage of the economic benefits offered by a new generation of heavy axle load freight cars, the Class I railroads began to upgrade their track structure to handle these cars in the late 1980s and early 1990s. As such, their current track structure, particularly their main lines and major secondary and branch lines which are constructed with heavy rail sections and adequate ties and ballast, are capable of handling these heavy cars.

Unfortunately, the track on Class II and Class III railroads is not in the same condition as Class I track. Many small railroads were organized to operate branch lines no longer needed or wanted by Class I railroads. Often, these lines were in relatively poor condition when the short line began operations.

With about 50,000 miles out of the total US railroad network's 218,000 miles, these short line and regional railroads represent just under one quarter of the US network. Yet their revenues represent less than 10% of the railroad industries gross revenues. As such, they have significantly less revenue per mile to maintain their track, resulting in a track structure that is often well below the standards of the main lines of the major freight railroads. Nevertheless, their physical plant must be capable of handling the heaviest freight cars allowed in interchange on North American railroads.

While the current level of track and structures is generally adequate for traditional railroad cars with 33 ton axle loads, is it often inadequate and potentially even unsafe for the new generation 286,000 pound cars with 36 ton axle loads. The result is a significant potential cost to short lines for upgrading their fixed plant (track and bridges) to handle cars of this weight.

Last year, ZETA-TECH Associates performed an assessment of the capital needs of the short line and regional railways to operate the new generation heavy axle load railways cars. This analysis was sponsored by the American Short Line and Regional Railroad Association and partially funded by the Federal Railroad Administration. The analysis quantified the total investment required of short line and regional railroad industry to ensure *the safe, long-term operation of heavier freight cars*. Many short lines now operate over marginal track, and while it is possible to maintain operations under such conditions, it is neither safe nor economical to operate in this manner over the long term. Therefore, the objective of this analysis was to make an engineering-based estimation of how much trackage meets a defined set of *minimum* criteria for operation of 286K cars and how much does not. Based on that analysis, the amount of component replacements required to bring the whole short line and regional railroad industry to an level of track condition adequate for safe, long term operations of the heavier cars was determined. This, in turn, was then used as the basis for the determination of the capital needs of the short line and regional railroad industry.

Analysis Methodology

The analysis approach used in this study was structured so as to allow for the evaluation of the capabilities of the track and bridge structures to handle the increased car weights for a large data set of short line and regional railroad information. The approach therefore combined engineering analysis and heavy axle load experience to create a series of evaluation steps to determine the adequacy of the track and bridges based on key component size and condition information.

In order to avoid the need to collect data from all 550 railroads, a sampling approach was used to collect in depth information from a representative group of short lines. This data, and the analysis results, was then generalized to the entire short line and regional rail industry. The target sample size for this analysis was 55 railroads and 5,000 route miles, or about 10% of the railroads and 10% of the track mileage in the industry.

In all, complete data was received from a total of 46 railroads, with 4,742 track miles. The 46 railroads in the sample ranged from small switching roads to medium-sized regional railroads distributed throughout the United States. The data collected was representative of the short line industry.

Following assembly of the database of track characteristics and condition, ZETA-TECH engineering models were used to determine the minimum track standards required to handle 286K cars. Using its proprietary engineering models, ZETA-TECH constructed a series of logic matrices in which each category of track component (rail, ties, ballast, turnouts) was evaluated as to its suitability to carry 286K loads in service. Using these individual component analyses, and their interactions, the combinations of components that were adequate, marginal, or required replacement in order to safely handle the heavier cars was determined as a function of speed and traffic density.

Logic matrices were developed for rails, ties, ballast, and turnouts, at different speed and density ranges. These were then applied to the data base of short line and regional railroad conditions.

Output of the ZETA-TECH analysis was a total amount of component replacement required, in terms of:

- Rail (track miles of rail required)
- Ties (number of required to achieve adequate condition and total mileage of track requiring tie renewals)
- Ballast (total track miles of ballasting required)
- Surfacing (performed whenever ballast is required)
- Turnouts (installed with rail), total number replaced

The quantities of rail, ties, ballast/surfacing, and turnouts required to handle 286K cars were then translated into dollars by use of standard costs for component replacements and other maintenance activities.

A separate analysis was also performed for bridges. Bridges had been identified as a potential problem in several previous heavy axle load studies by ZETA-TECH for Class I railroads. Therefore, they represented an area of potential concern that needed to be addressed. Since bridges are individual and unique, there is really no substitute for a detailed inspection of each. Nevertheless, an attempt was made to estimate the cost of needed bridge upgrading and replacement.

Based on information received from the sampling of short lines and regional railroads, a percentage distribution of bridge condition was developed. Multi-year budgets for bridge maintenance and rehabilitation prepared by a number of short lines were used in developing a cost of bridge repair for bridges in marginal condition. These represent expenditures needed to render bridges capable of handling 286K loads. Bridges in "poor" condition were assumed to require complete replacement, and standard industry costs were used in developing replacement costs. Calculations were made on the basis of the track feet of each type of bridge (wood, steel) on each railroad.

Results

Applying this analysis approach resulted in a summary of the amount of rail, ties, ballast, and turnouts, that have to be replaced to accommodate 286,000 lb. cars. In percentage terms, components needing replacement in the ZETA-TECH sample (and, by extension, the entire short line and regional industry) break down as follows:

- Rail — 22% of track miles must be replaced
- Ties — 43% of track miles require at least some ties
- Ballast/surfacing — 23% of track miles require ballasting/surfacing
- Bridges — 22% require replacement; 27% require upgrading

Using the unit costs for track and bridge upgrades/replacements, a total replacement cost for each category of expenditure was calculated. Table 2 shows the calculated total cost for the sample and its extension to the entire short line and regional rail industry.

Table 2: Calculated Cost of Upgrading Short Line and Regional Railroads to Handle 286,000 lb. Cars

Component	Required Investment per Mile	Total Cost (Sample)	Total Cost (Industry)
Rail	$75,106	$356,150,175	$3,754,182,002
Ties	$16,372	77,636,048	818,362,236
Ballast/Surfacing	$2,657	12,597,440	132,789,720
Turnouts	$7,882	37,377,454	393,996,056
Bridges	$35,236	167,085,889	1,761,253,773
Total	**$137,253**	**$650,847,006**	**$6,860,583,787**
Track Mileage		4,742	49,985

A comparison of the per mile costs develop in the ZETA-TECH analysis with two recent studies performed by the Kansas and Iowa Departments of Transportation provided additional support for the ZETA-TECH estimates. The ZETA-TECH estimate for track upgrading lies between the Kansas and Iowa estimates. The ZETA-TECH analysis uses new material costs, since there are simply not enough secondhand track materials to support a track upgrade program of this size (involving railroads with almost 50,000 track miles, and a total expenditure of close to $7 billion).

Thus, ZETA-TECH found a need for $6.8 billion in capital investment to upgrade short line track for the heavier cars now in operation on Class I railroads.

V. Summary

Analysis of the infrastructure condition of the U.S. railroad industry shows that while the Class I railroads track and structures are adequate for current operations, the smaller short line and regional railroads require significant capital outlays to enable them to operate the new generation of heavy axle load freight cars. Furthermore, the Class I railroads still require major capital outlays simply to maintain their infrastructure in its present condition.

Using its engineering based analysis models, ZETA-TECH calculated the Class I railroads' required annual level of capital investment needed to maintain its infrastructure. It also calculated the corresponding level of infrastructure maintenance (non-capitalized) required. Preliminary results indicate that the steady state level of spending required by Class I railroads, exclusive of short lines and regional railroads, is of the order of $8 billion per year for track and structures. This is based on a level of track condition that has already been upgraded to handle the new generation heavy cars. and which is significantly better than it had been in the 1970's and 1980's.

ZETA-TECH believes this level of investment is necessary over the long term to maintain the Class I network in its current condition. However, any reduction in this level of investment over time will result in a corresponding reduction in the quality of the infrastructure. In that case both safety and service would suffer.

Furthermore, any investments for expansion of capacity, to accommodate additional interurban or commuter rail service, or just more and heavier freight trains are above and beyond this level of spending. Thus, introduction of even heavier freight cars, such as the 315,000 lb. cars currently used on the mining railroads of Western Australia, will likewise increase the required level of capital outlays for track and structure.

In the case of the short lines and regional railroads, the current level of capital spending is not adequate to maintain their fixed plant. The ZETA-TECH study that established the capital needs for operation of 286,000 lb. cars also revealed that much of the rail on these railroads was old, many of the bridges were of marginal capacity or in poor condition. In general it determined that significant investment would be required even to return the network to a state of good repair capable of handling the current generation of heavy freight equipment now being operated by the Class I railroads.

The results of the ZETA-TECH study showed that short line and regional railroads need a one time investment of approximately $6.86 billion to upgrade their physical plant to allow for safe, effective, and long term operations under the new generation of railroad equipment that has been introduced into the industry.

Of this, more than 50% is for the replacement of rail. This is in line with Class I experience, where rail is always the largest track maintenance cost area. Smaller railroads, with lighter tonnage and more limited resources, have continued to use rail that would be removed from track by larger railroads. Thus, 22% of the rail on these smaller railroads need to be upgraded. Likewise, tie condition on these short lines and regionals is only fair, and the heavier 286,000 lb. cars demand better tie condition, in order to spread the 36 ton axle loads from rail to subgrade. Thus 43% of short line track miles need at least some ties. Likewise 23% of track miles require addition of ballast and surfacing to improve them for heavy axle loads.

There are also many miles of timber trestles on these rail lines. A large percentage will require increased maintenance, and many in poor condition will require replacement, in order to handle heavier cars. Steel bridges will also require significant investment to allow them to carry 286,000 lb. cars on an ongoing basis.

Finally, as freight car weights increase toward 315,000 lbs., as governments implement additional passenger train service, and as short lines are forced to handle heavier cars, railroad infrastructure requirements may be expected to increase even more in the future.

ALLAN M. ZAREMBSKI Ph.D., P.E.

Summary of Qualifications:

Over thirty years of professional engineering responsibility. Extensive experience in all areas of rail operations to include freight operations, transit, commuter and inter-urban. Internationally recognized expertise in the area of railway track and structures, railway operations, and track maintenance. Consulting services provided to virtually all major rail operations in North America together with numerous operations worldwide.

PROFESSIONAL HISTORY:

1984 to Present	**ZETA-TECH Associates, Inc., Cherry Hill, NJ** President Directed activities in track maintenance planning and planning software, rail and track analyses, economic analyses of railroad operations, and railway costing. Special areas of activity include railroad track structure, transit systems, and transportation planning.
1981 - 1984	**Pandrol Inc./Speno Rail Services Co.** Director Research & Development Dual responsibility for both companies in directing all research and development activities for new products, new systems, and future corporate activities. Reported directly to the President. Responsible for all railroad technology activities including product application, advertising, and technical support.
1976 - 1981	**Association of American Railroads** Manager - Track Research Division December 1978 to September 1981 Directed Division Responsible for conducting major research programs on railroad track. Directed AAR Track Laboratory. Conducted extensive field and laboratory tests as well as analytical research programs. Assistant Manager - Track Research Division August 1978 to December 1978 Initiated major research programs in Track Strength, Rail Fatigue, Ballast Failure Mechanisms, etc. Senior Research Engineer August 1976 to August 1978

Responsible for research programs on freight car fatigue design, rail overturning, and track gage widening. Developed test plans and procedures for AAR Track Laboratory.

1975 - 1976	**Princeton University** Research Associate - Dept. of Civil Engineering Conducted research activities in the area of lateral (railroad) track deformation and track buckling. Conducted laboratory tests at civil engineering laboratory.
1971 - 1973	**Grumman Aerospace Corp.** Engineer Responsibility for design and analysis of military aircraft structural components. Also conducted dynamic analyses of aircraft structures.

EDUCATION:

Sept. 1975	Ph.D. Civil Engineering; Princeton University
June 1974	M. A. Civil Engineering; Princeton University
Jan. 1973	M. S. Engineering Mechanics; New York University
Jan. 1971 York	B. S. (Magna Cum Laude) Aeronautics and Astronautics; New University

Short Courses:
Finance and Accounting for the Non-Financial Executive, The Wharton School, 1983.
The Art of Negotiation; The Negotiations Institute, 1982.
Managing People; The Wharton School, 1981.
Improving Your Management Performance; American Management Association 1981.
The Effective Engineering Manager; New York University, 1979.
Time Management for Engineers; American Management Association, 1979.
Effective Communications for Engineers; New York University, 1978.

PROFESSIONAL AFFILIATIONS:

Registered Professional Engineer: NJ, NY, PA, IL, MD

MEMBER:

American Railway Engineering and Maintenance of Way Association
American Society of Mechanical Engineers (Fellow)
American Society of Civil Engineers

HONORS AND AWARDS:

Elected to Fellow of the American Society of Mechanical Engineers in 2000

1992 Rail Transportation Award, American Society of Mechanical Engineers

Associate Editor, Railway Track and Structures Magazine, January 1985 to 1996. Author of monthly column; "Tracking R&D"

Adjunct Assistant Professor, Department of Civil Engineering, Illinois Institute of Technology 1980 - 1981

Instructor: Railroad Engineering Continuing Education Courses
Institute for Railroad Engineering; 1984 - present
George Washington University; 1980 - 1981
University of Wisconsin at Madison; 1978 -1981

Member: National Academy of Sciences, National Materials Advisory Board; Committee on Nondestructive Testing of Longitudinal Force in Rails

Member: Office for Research and Experiments of the International Union of Railway; Committee D150

Delegate: American Railway Engineering Association Railroad Delegation to the Peoples Republic of China, 1983

Deputy Director - International Government Industry Research Program on Track Train Dynamics

Author of over 90 papers on railroad track analysis and behavior, rail fatigue, and freight car design and analysis

Author of over 130 articles on railway operations and maintenance, published in all of the major U.S. and international (English speaking) industry publications

Author of the book <u>Tracking R&D; Research and Development</u>, Simmons Boardman, Omaha, NE, 1993

DR. ALLAN M. ZAREMBSKI

PUBLICATIONS

1. Zarembski, A. M., “Rail Rollover - The State of the Art”, **Bulletin of the American Railway Engineering Association, Bulletin 664, Volume 79**, September - October 1977.

2. Zarembski, A. M., “Freight Car Environment Characterization for Fatigue Life Analysis”, **Track/Train Dynamics and Design, Advanced Techniques**, Pergamon Press, N.Y., 1978.

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4. Abbott, R. A., & Zarembski, A. M., “On the Prediction of the Fatigue Life of Rails”, **Bulletin of the American Railway Engineering Association**, Bulletin 666, Volume 79, January - February 1978, p.p. 191-203.

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7. Zarembski, A. M., “Effect of Rail Section and Traffic on Rail Fatigue Life”, **American Railway Engineering Association, 78th Annual Technical Conference**, Chicago, IL, March 1979.

8. McConnell, D. P., Zarembski, A. M., & Lovelace, W. S., “Track Strength Characterization Program an Overview”, **American Railway Engineering Association, 78th Annual Technical Conference**, Chicago, IL, March 1979.

9. Darien, N. J., & Zarembski, A. M., “Railroad Freight Equipment Load Environment Testing”, **25th International Instrumentation Symposium**, Anaheim, CA, May 1979.

10. Torkamani, M. A. M., Bhatti, M. H., & Zarembski, A. M., “Dynamic Rail Overturning: Modeling and Application”, **Third ASCE/EMD Specialty Conference**, Austin, TX, September 1979.

11. Zarembski, A. M., & Rassasian, M., "Track Gage Widening A Model Study", **Transportation Engineering Journal**, American Society of Civil Engineers, November 1979.

12. Choros, J., & Zarembski, A. M., "Track Strength Vehicle Testing on High Curvature Mainline Track", **Rail International**, July 1982.

13. Abbott, R. A., & Zarembski, A. M., "Longer Rail Life is Goal", **Modern Railroads**, December 1978.

14. Torkamani, M. A. M., Bhatti, M. H., & Zarembski, A. M., "Dynamic Rail Overturning: Modeling", **Rail International**, September 1980.

15. Torkamani, M. A. M., Bhatti, M. H., & Zarembski, A. M., "Dynamic Rail Overturning: Application", **Rail International**, October 1980.

16. Zarembski, A. M., "On the Feasibility of Continuous Measurement of Track Gauge Restraint", **Rail International**, July - August 1980.

17. Zarembski, A. M. , "Rail Research: Meeting the Challenge of Modern Traffic Loading", Annual Meeting of the **Transportation Research Board**, January 1980. (Transportation Research Record 744).

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19. Lovelace, W. S., & Zarembski, A. M., "Future Directions in Track Evaluation and Inspection", **Track Train Dynamics Conference**, Chicago, IL, November 1979.

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