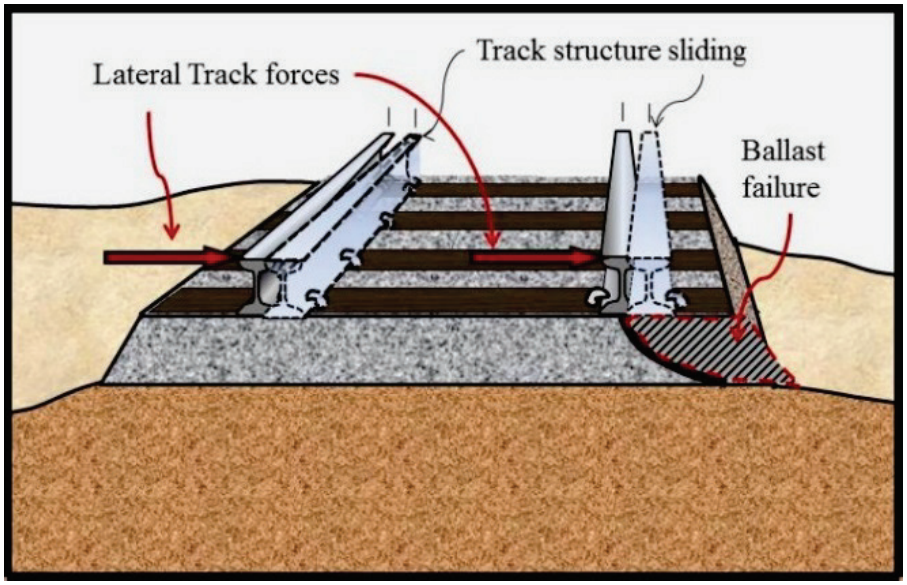
UNIVERSITY TRANSPORTATION CENTER FOR RAILWAY SAFETY

Exhibit F - UTCRS

UTC Project Information	
Project Title	Method for Predicting Thermal Buckling in Rails
University	Texas A&M University (TAMU)
Principal Investigator	David Allen, Ph.D., Civil Engineering (PI) Gary Fry, Ph.D., P.E., Civil Engineering (Co-PI)
PI Contact Information	3135 TAMU College Station, TX 77843-3135 Office (979) 458-8593 d-allen@tti.tamu.edu Office (719) 584-0641 Gary_fry@aar.com
Funding Source(s) and Amounts Provided (by each agency or organization)	Federal Funds (USDOT UTC Program): $150,000
Total Project Cost	$150,000
Agency ID or Contract Number	DTRT13-G-UTC59
Start and End Dates	May 2016 – December 2017
Brief Description of Research Project	A method is proposed herein for predicting the onset of thermal buckling in rails in such a way as to provide a means of avoiding this type of potentially devastating failure. The method consists of the development of a thermomechanical model of rail buckling, together with the construction of an on-the-fly experimental apparatus that is capable of concomitantly foretelling the onset of thermally induced rail buckling. As such, the combination of these two components is intended to provide a tool that can be employed as a means of determining when intervention is necessary in order to ensure that rails will not fail due to thermal buckling.

Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	<u>Description of noteworthy findings or advancement on the research:</u> A comprehensive literature review was performed, and it was determined that current technology has not produced a model capable of accurately predicting the onset of track buckling. This appears to be due to the fact that the crosstie-ballast interface undergoes highly nonlinear and history dependent friction that decays with rail tonnage. Although some preliminary research was previously performed on the effect of friction, it was not taken to the point of a practical model. Thus, research was undertaken to construct a nonlinear finite element model for the purpose of accounting for the effect of nonlinear friction on track buckling. One report was produced that focused on the construction of a practical phenomenological model of the nonlinear friction, and a second report was produced that details the finite element model employed to model track buckling.  **Figure 1: Illustration of deformation mechanisms in track structure caused by lateral loading.** A significant feature of the model is the ability to account for the degradation of material properties within the track structure that arise from cyclic loading and environmental conditions. Toward this end, a model for predicting the coefficient of friction between the crossties and ballast as a function of loading history was developed.

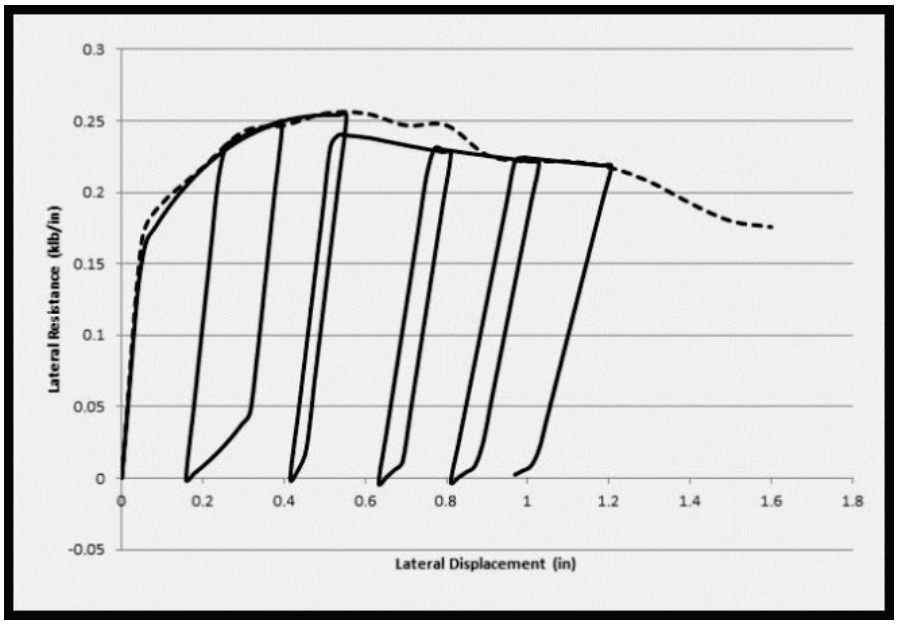


Figure 2: Predicted lateral resistance versus applied lateral displacement.

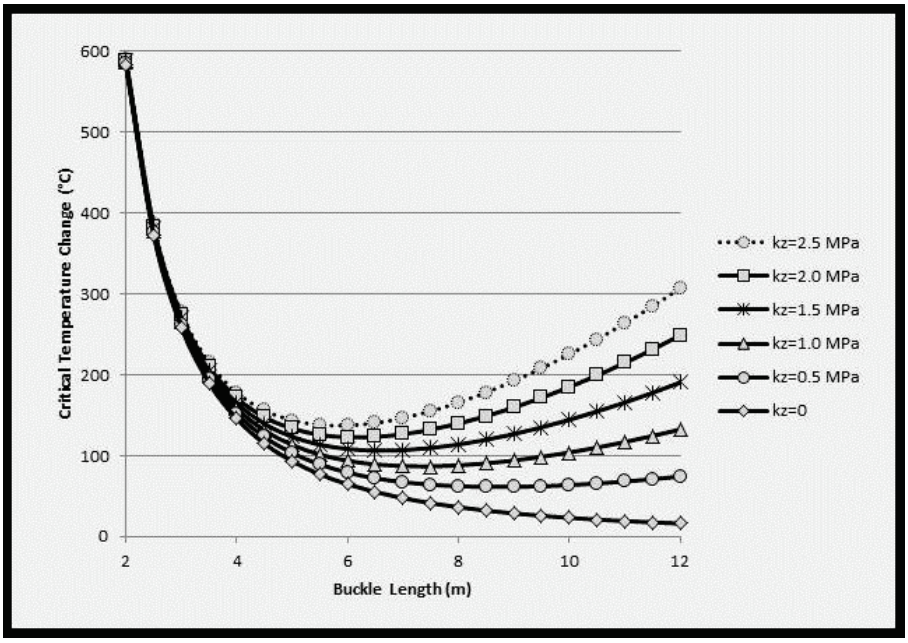


Figure 3: Predicted critical temperature change for rail buckling as a function of buckle length for several different friction coefficients.

Impacts/Benefits of Implementation (actual, not anticipated)	While the model has not yet been implemented, it has been presented at the 2017 International Heavy Haul Association (IHHA) Conference, and documented for public consumption in the conference proceedings. In addition, the resulting computational algorithm has been ported over to the Technology Transportation Center for implementation into track buckling sensing strategies. The following reports, articles, and papers have resulted from this project: 1. Allen, D.H. and Fry, G.T., "A Model for Predicting Lateral Buckling in Rails," *Proceedings of the 11th International Heavy Haul Association Conference*, Cape Town, South Africa, September 2-6, 2017. 2. Allen, D.H. and Fry, G.T., "Predicting Lateral Buckling in Rails," *Railway Track & Structures (RT&S) Magazine*, pp. 10-12, April 2017. Access at: https://issuu.com/railwaytrackstructures/docs/rts_april_2017/12 3. Allen, D.H., Fry, G.T. and Davis, D., "Development of a Model for Describing Nonlinear Lateral Resistance of Track Ballast," Technology Digest, TD-16-029, June 2016. 4. Allen, D.H. and Fry, G.T., "Finite Element Formulation for Thermal Buckling of Rails," Center for Railway Research, Texas A&M University, CRR-2016-02, 2016. 5. Allen, D.H. and Fry, G.T., "Analysis of a Rail Subjected to Mechanical and Thermal Loading," Center for Railway Research, Texas A&M University, CRR-2016-01, 2016.
Web Links • Reports • Project Website	http://www.utrgv.edu/railwaysafety/research/infrastructure/thermal-buckling-in-rails/index.htm