Class III / short line system inventory to determine 286,000 lb (129,844 kg) railcar operational status in Kansas and determination of ballast fouling using ground penetrating radar

by

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Abstract

The rail industry's recent shift towards larger and heavier railcars has influenced Class III / short line railroad operation and track maintenance costs. Class III railroads earn less than $38.1 million in in annual revenue and generally operate first and last leg shipping for their customers. In Kansas, Class III railroads operate approximately 40 percent of the roughly 2,800 miles (4,500 km) of rail; however, due to the current Class III track condition they move lighter railcars at lower speeds than Class I railroads. The State of Kansas statutorily allots $5 million to support rail improvement projects, primarily for Class III railroads. Therefore, the objective of this study was to conduct an inventory of Kansas's Class III rail network to identify the track segments in need of this support that would be most beneficial to the rail system. Representatives of each railroad were contacted and received a survey requesting information regarding the operational and structural status of their systems. The data collected were organized and processed to determine the sections of track that can accommodate the heavier axle load cars that are currently being utilized by Class I railroads. This study identified that Class III railroads shipped over 155,000 carloads of freight in 2016 and 30 percent of Kansas's Class III track can currently accommodate heavy axle cars.

The increased load from the increased railcar size has also increased the risk of damage to railroad's track structure. Railroad ballast is the free draining granular material that supports the track structure. As the track ages, small particles can fill the voids of the granular material which is a process known as fouling. Established methods for determining the fouling of a section of ballast are destructive tests that usually require the railroad to restrict or reroute traffic on its network. Ground Penetrating Radar (GPR) is a nondestructive geophysical surveying method that measures the time required for electromagnetic wave impulses to reflect off differing subsurface

interfaces. Historically, GPR surveys of track structures primarily determine the depth of ballast and track geometry. The objective of this study was to determine the viability of utilizing the laboratory's existing GPR equipment to develop a methodology of measuring ballast fouling nondestructively. A 48 x 48 x 48 in (1.2 x 1.2 x 1.2 m) test box was built. The test box was filled with 48 in (1.2 m) of clean and ballast. Tests were run on dry and partially saturated material, wetted using 6 gallons (22.7 L). GPR data were collected hourly for the first 6 hours, then at the multiples of 12 and 24 hour marks for one week. Sand was chosen as an absorbent geologic material for the second stage of testing since no fouled ballast could be acquired at the time of the study. A 27 x18 x 18 in (0.69 x 0.46 x 0.046 m) box was filled with sand and wetted with water in one gallon (7.5 L) increments. GPR scans and samples to determine the water content were collected after the addition of each gallon. The data collected were processed to determine soil properties. Preliminary results from this research indicate that the GPR set up utilized can effectively determine the dielectric constant of geologic materials including ballast, although the dielectric constant is highly dependent on the volumetric moisture content of the material.

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Chapter 1 - Introduction

Railroad operations are the primary means of transporting goods, people, and services across the state of Kansas. To maintain and improve its Class III railroad network (i.e., track structures, bridges, and at-grade crossings), the Kansas Department of Transportation (KDOT) distributes state funding in the form of grants and loans to private railroad companies and parent companies. Parsons Brinkerhoff reviewed the Kansas Class III Railroad Rehabilitation Program for KDOT, concluding that the program was a worthy investment of state taxpayer funding because it benefited private and public sectors (Parsons Brinkerhoff, 2005). The study also determined the combined 10-year present value of public sector benefits for state and local tax revenues and highway maintenance cost savings to be $43.7 million. Parsons Brinkerhoff found the combined direct and indirect benefits to the private sector from rehabilitation projects surpassed $1 billion in business earnings and $425 million in personal wage income. The report also recommended that a Class III railroad infrastructure inventory assessment should be conducted to document and inventory infrastructure needs of the Class III railroad system in Kansas. A Class III inventory would prioritize and optimally distribute funds to high-volume priority Class III corridors.

1.1 The Kansas Rail System

The active portion of Kansas's freight rail system consists of 17 railroads, including three Class I railroads (annual revenue more than $475 million), 11 Class III carriers (annual revenue less than $38 million), and three switching and terminal railroads, mapped in Figure 1.1. The Class I railroads include Union Pacific (UP), Burlington Northern Santa Fe (BNSF), and Kansas City Southern, collectively operating approximately 2,790 miles (4,490 km) of track in Kansas. The Class III railroads collectively operate approximately 1,600 miles (2,575 km) of track, accounting for slightly more than 40 percent of all route mileage in Kansas (KDOT, 2011).

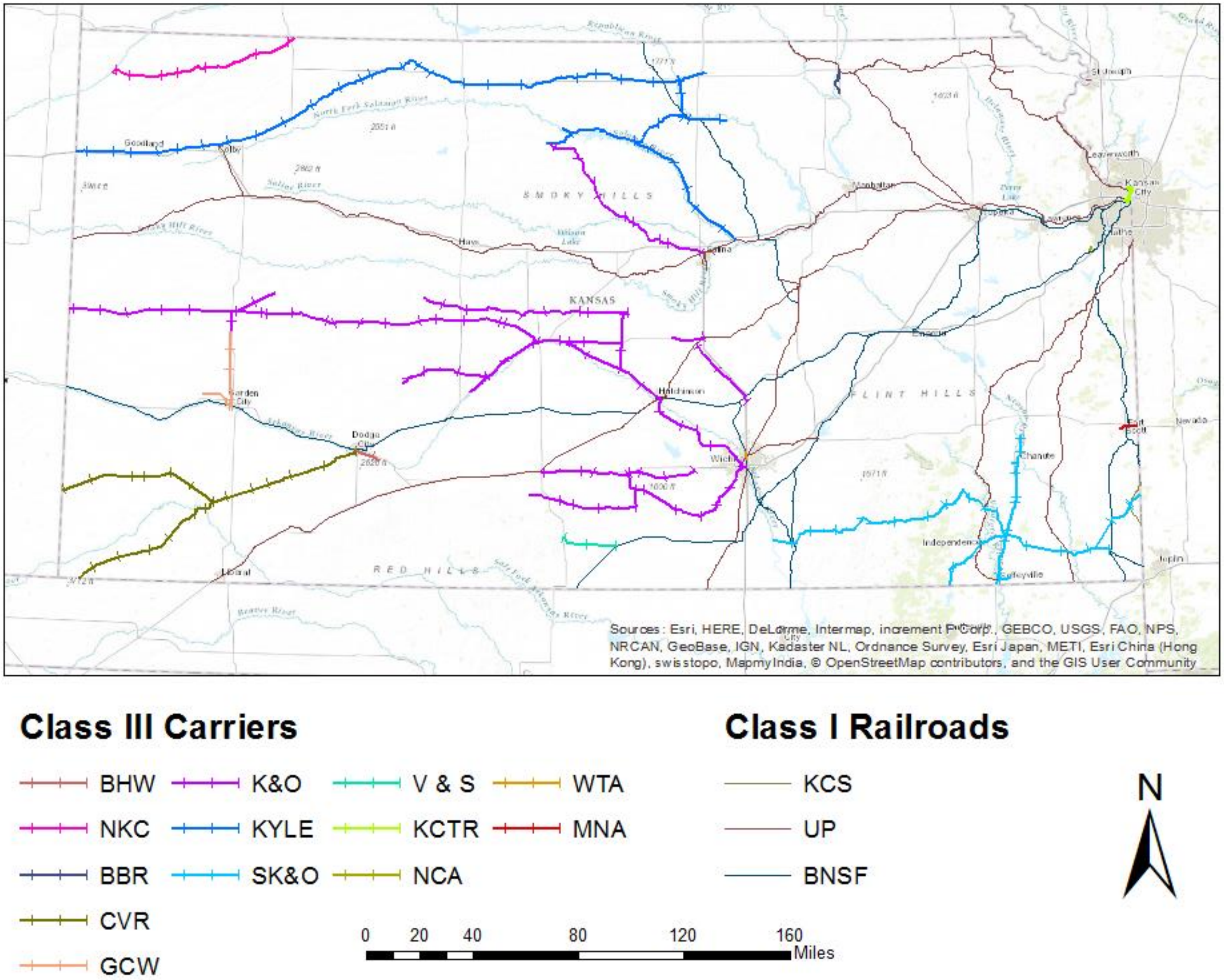

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Figure 1.1 Active Freight Railroads in Kansas (2017)

Class I railroads have historically upgraded track sections based on business demands and lines that terminate or run through the State of Kansas. This distinction means that not only can Class I railroads operate at faster speeds (above 50 mph (80 kmh) versus 10 to 30 mph (16 to 48 kmh)), but they also are capable of supporting and pulling heavier railcars (286,000 lb (129,844 kg) instead of 263,000 lb (119,294 kg)). As multimodal freight shipments are now commonly utilizing 286,000 lb (129,844 kg) on the Class I network, it has become difficult financially for the Class III railroads to upgrade their track structure to accommodate the additional weight and increase operating speeds to accommodate current freight demands (KDOT, 2011).

1.2 History of the Kansas Rail Funding Programs

In the late 1980's KDOT became administrator over the federal Local Rail Freight Assistance (LRFA) Program. The goal of the LRFA was to disperse Federal Railroad Administration (FRA) funding in the form of loans to support improvement projects for small railroads, including Class III railroads. Interest earned from LRFA loans helped generate additional loans. Although FRA funding for this program ended in the early 1990s, however success of the loan-based program encouraged the state of Kansas to establish its own state-funded assistance program (through KDOT) to address track structure upgrades of Class III railroads.

In 2000, KDOT developed the Comprehensive Transportation Program (CTP) to manage and improve Kansas's multimodal transportation network, which consists of trucking, rail, and air. The CTP utilized the State Rail Service Improvement Fund (SRSIF) to provide low-interest loans and grants to rehabilitate track structures of Class III railroads in Kansas. The SRSIF program provided $3 million annually in loans and grants to Class III railroads from 2000 to 2008. After which time, the program was planned to become self-sufficient due to the interest earned from loan repayments (Parsons Brinkerhoff, 2005). In 2001, however, the state of Kansas faced the pending abandonment of the Central Kansas Railway (CKR), a central 900-mile (1,450 km) section of the Class III network. To maintain operational feasibility and key rail corridors of this railroad in west-central and south-central Kansas, a portion of SRSIF program funds were granted to expedite acquisition of the CKR from a bankrupt company to a growing parent company.

Following Kansas legislative action in 2012 and in conjunction with the Transportation Works for Kansas (T-Works) program, the SRSIF now statutorily allots $5 million annually to track improvement projects primarily for Class III railroads. To apply for a state loan or grant through the SRSIF program, proposed projects must follow a 40-30-30 distribution in which 40 percent of the capital cost is a loan with a 2 percent interest rate that must be paid back within 10 years, 30 percent is matched as a grant by the state of Kansas, and the remaining 30 percent must come from the project applicant. Class III railroads applying for loans or grants must prove that the proposed upgrade will increase operations efficiency by either increasing the track's weight capacity (for heavy railcars) or meeting an FRA-mandated speed limit increase. Proposed projects are evaluated based on a cost-benefit analysis and are ranked for consideration. The cost-benefit analysis considers the project cost, customer needs, existing rail carloads, anticipated railcar loads based on proposed improvements, and public sector benefits (PB, 2005; KAR, 2012).

1.3 General Rail Inspection Methods

The increase in average gross weight of railcars seen since the 1970's has naturally coincides with increased loads supported by the track structure. These larger loads have resulted in Class I railroads strengthening their track maintenance schedules for their track segments with heavy volumes. A common issue that they inspect for in high traffic areas is ballast fouling, which occurs primarily due to track degradation. Ballast fouling decreases the drainage ability and the shear strength of tracks. Conventional methods to determine sections of fouled track usually require physical sample acquisition which negatively impacts the railroads' ability to operate by requiring the railroad to reroute traffic. Ground penetrating radar (GPR) has the potential to locate fouled sections of track while maintaining normal operations of traffic or requiring the acquisition of lab samples.

1.4 Study Objectives

KDOT's continuation of the SRSIF program highlights its confidence that the Class III railroad system will continue to be a logistically and economically sound option for freight transportation. The primary objectives of this study was to determine the present state of the rail system in Kansas and guide future SRSIF rail improvement projects to maximize benefits for shippers, railroads, and the state by creating an inventory and synthesis of existing track locations. Quantiles were developed to relate track structure and business data for Class III railroads in Kansas. Collected Class III railroad data were used to identify high-priority track corridors as potential candidates for SRSIF funding.

The secondary objectives of this research were to investigate the feasibility and develop a methodology to utilize ground penetrating radar (GPR) to quantify the degree of fouling present in railroad ballast. These were achieved by acquiring the GPR response of clean ballast and sand (due to the inability to obtain fouled ballast) with varying water contents. The scans obtained were used to calculate geotechnical properties of each of the materials. This methodology will allow future researchers to investigate a novel approach for using GPR on ballast surveys to reduce the inherent uncertainties when transitioned to the field

1.5 Thesis Outline

Following this introduction is a review of literature examining the economic feasibility of Class III railroads, the effect of heavy axle loads on the Class III rail system, and methods of funding Class III railroad improvement projects, as well as details of the source, effect, and detection of ballast fouling focusing on ground penetrating radar (GPR) which details its fundamentals and previous rail-related GPR research. Next, an overview of the research methodology is given including the Class III survey development and distribution as well as the laboratory set up and instrumentation of the GPR research. Subsequent sections document the survey results for the entire freight rail system and individual Class III railroads in Kansas as well as the results of the ballast and sand testing. Finally, conclusions are presented as well as research recommendations including a tiered system to prioritize the importance of upgrading rail corridors to accommodate 286,000 lb (129,844 kg) railcars and a review of the ballast/sand study and the future work to continue the research.

Chapter 2 - Literature Review

Since the Civil War, railroads have played an important role for the American economy by connecting the coasts. This allowed for easy transportation of goods and services between major cities and waterway ports. Today, the United States (U.S.) freight railroad system operates nearly 140,000 miles (22,530 km) of centerline track, handles more than 40 percent of intercity freight volumes, and supports an average of 4.5 jobs in other related sectors of the economy for every internal freight rail job these companies provide (AAR, 2014). The American Short Line and Regional Railroad Association (ASLRRA, 2014) states that Class III railroads account for approximately 43,000 miles (69,200 km) of centerline track in the U.S., haul more than 8 million carloads of goods each year, and serve the economy by cost effectively allowing easy access to markets and ports across the country. Currently, there are over 560 Class III railroads, which strategically connect private industries, farms, factories, and waterway ports to the major Class I freight railroads in the U.S. (ASLRRA, 2014). The purpose of this chapter is to provide a background on Class III railroads including: how they affect society, the challenges faced by Class III railroads due to the industry's shift towards heavy axle loads, and a synopsis of current methods for funding Class III railroad improvements, as well as an investigation on an improved method of track inspection.

2.1 Railroad Classifications

Since the1860's, during the Civil War railroads have been essential to the American economy because they connect the coasts, allowing straightforward transportation of goods and services between major cities and waterway ports. The freight railroad system in the United States currently contains nearly 140,000 miles (22,530 km) of centerline track, accommodates more than 40 percent of intercity freight volumes, and provides an average of 4.5 jobs in related sectors for every internal freight rail job (AAR, 2014). The American Short Line and Regional Railroad Association (ASLRRA) states that Class III railroads encompass approximately 43,000 miles (69,200 km) of centerline track in the United States, accounting for more than 8 million carloads of goods each year and cost-effectively allowing access to markets and ports throughout the country (ASLRRA, 2014). Currently, more than 560 Class III railroads strategically connecting private industries, farms, factories, and waterway ports to major Class I freight rail network in the United States (ASLRRA, 2014). This chapter provides background on Class III railroads, including how they affect society, challenges faced by Class III railroads due to the shift towards HAL railcars, and a synopsis of current methods for funding Class III railroad improvements.

2.1 Railroad Classifications

The Surface Transportation Board (STB) has broad economic regulatory oversight for most modes of freight shipping in the United States, such as pipeline carriers, intercity bus carriers, trucking companies, and railroads, including shipping rates, service, construction, acquisition and abandonment of rail lines, carrier mergers, and classification of railroads (FRA, 2014). Class I railroads are private corporations consisting of expansive stretches of track that span across many states that typically allow trains to travel up to 60 mph (97kmh).. Class II and III railroads are often referred to as regional and local, or short line, railroads, respectively, and they primarily provide services for commodity groups based on area of operation, such as grain and non-grain food and farm products in the western two-thirds of Kansas. However, Class II and III railroads operate at slower speeds than Class I railroads due to inferior quality track structure, older rolling stock, lighter traffic densities, and shorter shipping distances between origin of goods and final destinations. Due to their smaller physical and operating sizes, Class II and Class III railroads can readily cater to customer needs and adapt operations to meet those needs, including switching operations or increasing grain fleets to accommodate fruitful grain harvests (Allen et al., 2002; ASLRR, 2014).

Railroad classification is based on the railroads' gross annual operating revenues based on dollar values from the year 1991 and adjusted annually for inflation (Federal Register, 2015). Table 2.1 shows the defined ranges that specify railroad class based on annual operating revenues for the base years of 1991 and 2014.

Table 2.1 Categories for Railroad Classification According to the STB (Federal Register, 2015)

Class	**Annual Carrier Operating Revenues in 1991 dollars in millions**	**Annual Carrier Operating Revenues for 2014 dollars in millions**
I	more than $250	more than $475.7
II	more than $20 but less than $250	more than $38.1 but less than $475.7
III	less than $20	less than $38.1

As shown in Table 2.1, Class I railroads have annual carrier operating revenue greater than $250 million, Class II railroads have annual carrier operating revenue between $20 and $250 million, and Class III railroads have annual carrier operating revenue less than $20 million. For dollar values in the year 2014, then, these values translate into more than $475.7 million for Class I railroads, between $38.1 and $475.7 million for Class II railroads, and less than $38.1 million for Class III railroads. Regardless of annual operating revenues, all switching and terminal railroads, or urban-centered operations that primarily transfer goods to other railroads or businesses that transport freight, are labeled as Class III railroads. Switching and terminal railroads usually have rail yards to reorder or store railcars for customers. Reclassification occurs after a railroad's operating revenues meets the requirements of a different classification bracket than its current ranking for three consecutive years (FRA, 2014).

2.2 Staggers Act and the Influx of Class III Railroads

Approximately 240 non-Class I railroads were in operation in the United States in 1980, and as of 2014, 560 Class II and III railroads were operating within the country (ASLRRA, 2014). The Staggers Rail Act of 1980, which deregulated and significantly altered the railroad industry, was the primary contributing factor for the proliferation of non-Class I freight railroads. The Staggers Act also simplified the procedure for selling sections of track and decreased the time required to process such transactions (Allen et al., 2002). As a result, less profitable sections of Class I track were sold to investors instead of undergoing abandonment, thus conserving shippers' access to a railroad and preserving rail system connectivity (Witt, 2004). The Staggers Act was instrumental in the creation of almost all Class II and III railroads in the United States. Prior to 1980 most Class III railroads were owned and operated by small, independent, family-oriented businesses. Today, however, the largest proprietary stake in the Class III railroad industry is held by holding companies that own multiple railroads throughout the country (Allen et al., 2002).

2.3 Economic Effects of Class III Railroads

The actual economic effect of Class II and III railroads are often underestimated because the railroads typically supply localized services. Multiple research studies have focused on various factors of influence in order to quantify the effects of Class III railroads on local economies.

2.3.1 Employment Effects

Class III railroads often create numerous jobs and attract businesses to local regions. Llorens and Richardson (2014) investigated the relationship between Class III railroads and increased job opportunities in Louisiana. The research team obtained data by conducting a survey of Louisiana's Class III railroads. Survey results showed that Class III railroads directly employ 330 individuals annually, offering an average of $67,000 in wages and benefits per individual.

Results also showed that the railroads indirectly support an additional 1,500 jobs, consequently benefiting the state's economy, especially Louisiana's impoverished communities. These jobs contribute approximately $3.5 million and $2.86 million annually in state taxes and local revenues, respectively (Llorens and Richardson, 2014).

Miller and Stich (2013) investigated the effects of the Class III railroad industry on economic development in Mississippi, determining that an estimated $273 million capital investment was needed to upgrade all Mississippi's Class III railroads for full operation with no impending degradation of track quality. They also calculated the number of expected direct and indirect jobs created by such an investment and compared this data to previous data of jobs created by publicly funded automotive assembly plants, as shown in Table 2.2.

Table 2.2 Comparison of Economic Development Expenditures per Job Created (Miller and Stich, 2013)

	Public Financial Assistance (in millions)	Direct and Indirect Jobs Created	Public Expenditure per Job Created
Mississippi Class IIIs	$273	66,430 over 30 years	$4,000
Toyota Assembly Plant	$356	4,000 in 5 years	$89,000
Nissan Assembly Plants	$363	4,000 in 5 years	$90,000

Miller and Stich (2013) determined that the $273 million invested in the Mississippi Class III industry would create 66,430 jobs over 30 years. In contrast, the Toyota and Nissan assembly plants would create 4,000 jobs at much higher costs of $356 and $363 million, respectively, proving that investments in a Class III railroad create new jobs approximately 22 times more effectively than the automotive assembly plants. However, Miller and Stich readily admitted that their estimation was a simplified comparison and that many more factors must be investigated to design effective local economic development strategies in correlation with Class III railroads.

Factors requiring further investigation include public opinions, actual funding sources, and situational variables (Miller and Stich, 2013).

A study conducted by Feser and Cassidy (1996) warned against overly optimistic economic development projects for Class III railroad projects. The authors reviewed 14 studies involving Class III railroads and compared the estimated versus actual experienced economic effects of the Class III railroads. They found that the estimation of employment influences had the largest degree of discrepancies between the expected and actual economic impacts of Class III railroad projects, and they proposed three factors that contributed to these inconsistencies. First, the data used for estimations based on rail users overestimated the impact a service change would have on the rail's businesses. Second, assessment of the actual proportion of total employment created can be difficult to calculate, requiring transfers of employment to be distinguished as true jobs or wage gains. Third, an industrywide lack of evaluation of estimations after completion of projects that potentially contributes to continuous overestimation of job creation rates of Class III rail projects (Feser and Cassidy, 1996).

2.3.2 Abandonment Effects

Another common method to estimate regional impacts of a Class III railroad simulates the abandonment of all or portions of the railroad network. Babcock et al. (2003) investigated the impact of Class III railroad abandonment in the state of Kansas by simulating the complete transfer of all wheat production in the western two-thirds of Kansas from Class III railcars to trucks. The researchers used geographic information system (GIS) software to calculate the minimum transportation and handling costs required to move wheat from Kansas farms to export terminals in Houston, Texas. The authors found that increased costs to transport wheat products to export terminals via trucks decreased financial gains for wheat producers. The authors also estimated pavement damage costs due to complete railroad network abandonment by converting the amount of wheat usually transported by rail to truckloads and then estimating the increased damage trucks would cause to the pavement. The study concluded that total Class III abandonment would reduce Kansas farm income by $17.4 million per year due to increased shipping and handling costs and cause $57.8 million in highway damage per year due to increased truck mileage (Babcock et al., 2003).

Witt (2004) improved the methodology for estimating the effect of railroad track abandonment on highway safety by accounting for the costs and benefits of stopping operations of railroads. Like Babcock et al., Witt also simulated the total abandonment of Class III railroads in the western two-thirds of Kansas and determined that corresponding truck traffic must accommodate wheat typically shipped in railcars. Witt took into account that freight shipment from rails to trucks reducing the occurrence of crashes involving trucks due to the removal of at-grade rail crossings in rural regions. The costs and benefits of the change were based on the average cost and number of crashes per truck mile traveled, and annual collisions at highway-rail crossings with no rail traffic. Witt found the net annual safety cost to be $1.3 million and the net annual safety benefit to be $2.7 million. Thus, the net annual safety impact of rail abandonment would be an annual savings of $1.4 million primarily due to the reduction of crash-prone at-grade rail crossings (Witt, 2004).

Bitzan and Toliver (2001) compared total highway impact costs of all North Dakota Class III railroads with less than 150 cars per mile running on rails less than 90 lb/yd (44.6 kg/m) to the total cost to upgrade the 1,200 miles (1,930 km) of track in North Dakota to accommodate 286,000 lb (129,844 kg) railcars. They used a method similar to Witt (2004) to calculate total economic effect on the state's highways, determining that, although the change in shipping mode could cost the state of North Dakota $73 million, the cost to completely upgrade the lower quality Class III track would exceed $257 million. Therefore, a complete upgrade of the railroad network is highly unfeasible, but the researchers suggested that the improvement of sections of certain railroads may be economically feasible, consequently earning justly awarded subsidies (Bitzan and Toliver, 2001).

Zink (1984) investigated the economic viability of converting Class III railroads instead of abandoning low-volume track miles in grain-shipping regions of North Dakota. Zink estimated the total revenue for converting abandoned rail segments into Class III railroads under five separate scenarios in a heavily grain-dependent market, accounting for necessary rehabilitation costs, maintenance, interest rates, and earnings per railcar. Each scenario predicted a shortfall of $500,000 to $1.1 million per year, meaning that unless high volumes of grain or similar commodities were shipped, acquisition of sufficient revenue to justify the conversion of abandoned lines to Class III railroads would be difficult.

Sage et al. (2015) estimated the economic impact for three Class III railroads in Washington state. The costs of transporting commodities using Class III railroads in 2013 were estimated for three situations: use of rail only, use of trucks and rail, and use of trucks only. These costs were then compared to the product value. For each situation the shipping distance used to determine the transportation cost was based on nationwide averages for each commodity group. Results of this study for the Columbia Basin Railroad are shown in Table 2.3.

Table 2.3 Travel Cost Scenarios for Transport Diversion from Rail to Truck of the Columbia Basin Railroad (from Sage et al., 2015)

Commodity	Total Estimated Value of Product Moved	Total Estimated Cost of Movement by Rail	Cost if Truck Rail Combination	Cost if Moved Fully by Truck
Food or Kindred Products (STCC 20)	$624,843,750	$21,176,145	$28,387,861	$251,561,254
Farm Products (STCC 01)	$69,253,032	$2,937,626	$7,485,749	$34,897,418
Chemicals or Allied Products (STCC 28)	$71,177,775	$2,711,296	$5,439,809	$32,208,744
Hazmat (STCC 49)	$62,602,000	$2,968,376	$4,966,521	$35,262,720
Pulp, Paper or Allied Products (STCC 26)	$28,616,327	$1,249,382	$2,006,802	$14,841,994
Non-Metallic Minerals (STCC 14)	$485,182	$232,332	$742,688	$2,759,976
TOTAL	$856,978,067	$31,275,157	$49,029,433	$371,532,106

As show in in Table 2.3, the estimated value of goods shipped was approximately $857 billion, and the total cost for shipping goods by rail only was approximately $31 billion. If the movement of goods was changed to a rail and truck or truck only, the shipping cost would increase to approximately $49 billion and $371 billion, respectively.

2.3.3 Summary of the Effect of Class IIIs

The effect of Class III railroads vary regionally and by railroad, as indicated by the mentioned studies. Although Class IIIs railroads are a significant source of employment and support several regional industries, simple methods often overestimate the value of these railroads (Llorens and Richardson, 2014; Miller and Stich, 2013; Babcock et al., 2003; Freser and Cassidy, 1996). Therefore, most Class III rail improvements are based on robust cost-benefit analyses that include improved operating performance, customer service, and safety. The removal of Class III railroads and the use of large trucks to transport products have increased shipping costs for local industries and annual highway damage costs but have decreased state highway costs increasing the net annual highway safety (Babcock et al., 2003; Witt, 20004; Sage et al., 2015). However, costs required to upgrade Class III railroads to optimal working conditions are not justified due to lack of adequate traffic generation (Bitzan and Toliver, 2001; Zink, 1984).

2.4 Heavy Axle Loads

Railroad technology is continually progressing, and the ability to improve and innovate the size and shape of railcars has led to the creation of many shipping options for goods and services. One type of railcar, the large HAL railcar, can transport large volumes of goods, but it increases stress on the track. The Heavy Axle Load Research Program, administered by the Association of American Railroads (AAR) and conducted from 1988 to 2000, attempted to develop HAL guidance for the North American railroad industry to determine the safest and optimum economic payload for bulk shipments (Martland, 2013). In 1991 a railcar with a 286,000 lb (129,844 kg) gross value weight became the new industry standard for a cost-effective HAL instead of the previous 263,000 lb (119,295 kg) gross value weight (Martland, 2013). The new cost effectiveness was attributed to increased savings in operating costs for the railroads compared to the corresponding increase in track maintenance and equipment costs. Operation costs for the heavier railcars proved to be approximately 9 percent less than the lighter cars due to the decreased number of carloads needed to haul the same volume of goods (Casavant and Tolliver, 2001). Although the increased stress applied by HAL traffic to the track structure was expected to increase railroad expenditures by $50 or $60 million per year, in actuality, the constant dollar infrastructure expenditure per 1,000 revenue ton-miles decreased from $10.25 million in 1990 to $9.41 million in 2010 as a result of enhanced technology and improved track maintenance methods and the fact that not all railroad tracks are currently maintained sufficiently to accommodate HAL railcars (Martland, 2013).

Resor et al. (2000) investigated minimum track requirements to accommodate HALs, determining that a railcar weighing over 286,000 lb (129,844 kg) on a track structure with rails less than or equal to 70 lb/yd (35 kg/m) is likely to deteriorate quickly, and may cause derailments, but 90 lb/yd (45 kg/m) rail may perform satisfactorily depending on the track substructure quality and train speed. Finally, 112 lb/yd (55 kg/m) rail with average track support performs satisfactorily with train speeds up to 40 mph (64 kmh). The authors recommended that all tracks with less than 90 lb (45 kg/m) rail should be upgraded to 112 or 115 lb/yd (55 or 57 kg/m) rail so that trains can operate at or above 25 mph (40 kmh). Additionally, all jointed 90 lb/yd (45 kg/m) rail in service should be welded into longer sections to lessen dynamic effects and increase continuous support (Resor et al., 2000). However, research results showed that most rail sections with 90 lb/yd (45 kg/m) or less are owned by small, low-volume railroads that do not generate enough revenue to improve track structure conditions.

2.4.1 Impact of Heavy Axle Loads on Class III Railroads

Most Class IIIs railroads have been acquired by private companies from low-performing branch lines of Class I track that currently may be suffering from decades of deferred maintenance, preventing many Class III railroad networks from accommodating trainsets with HAL railcars. Several research studies have attempted to quantify funding required to upgrade rail segments to accommodate HAL railcars and increased train speeds. Babcock and Sanders (2004), Casavant and Tolliver (2001), and Bitzan and Tolliver (2001) investigated upgrade costs for Kansas, Washington state, and North Dakota, respectively. Additionally, Resor et al. (2000) investigated ways to calculate the current conditions and needs of Class III railroads on a national level.

Babcock and Sanderson (2004) researched the effects of 286,000 lb (129,844 kg) railcars on five Class III railroads in Kansas. They surveyed representatives of these railroads and found that approximately 70 percent of the total mainline route miles and 86 percent of the total number of bridges must be upgraded to safely accommodate HAL railcars. The total cost of the proposed upgrades was estimated to be approximately $308.7 million (Babcock and Sanderson 2004).

Casavant and Tolliver (2001) estimated the cost of upgrading light-density segments of track in Washington state to handle carloads weighing 286,000 lb (129,844 kg). The authors estimated upgrade costs to be between $250,000 and $300,000 per mile ($156,000 and 186,000 per km) of track, not counting any bridge upgrade costs. The researchers estimated that 482 miles (776 km) of track must be upgraded, resulting in a minimum rehabilitation cost between $117 million and $141 million, including the use of second-hand rail and limited replacement of crossties (Casavant and Tolliver, 2001).

Bitzan and Tolliver (2001) simulated the effects of the use of HAL railcars to determine if a Class III railroad would be a beneficial investment for North Dakota. They determined that approximately 1,200 miles (1,931 km) of track would need to be upgraded for the rail system to fully accommodate HAL cars and that upgraded track sections would cost between $258 million and $324 million, excluding any necessary bridge rehabilitations. Using an internal rate of return to determine the economic feasibility of upgrading track, they found that minimum traffic needed to justify upgrading Class III track was more than 200 cars per mile (125 cars per km). However, for Class I railroads with shipping competition nearby, minimum necessary traffic was as low as 40 cars per mile due to their higher revenues (25 cars per km) (Bitzan and Tolliver, 2001).

Resor et al. (2000) surveyed a representative sample of 46 Class III railroads throughout the United States, which was slightly less than 10 percent of the industry at the time. The objectives of the survey were to determine existing track conditions and calculate improvement costs to determine the total cost of upgrading the national Class III system. They found that approximately 23 percent of national rail needed to be replaced, 43 percent of ties needed to be replaced, 23 percent of the track mileage needed ballast and resurfacing, 22 percent of bridges needed to be completely replaced, and another 27 percent of bridges needed upgrading, requiring a total of $650 million to perform maintenance work for the surveyed sample. When translated to the entire Class III rail industry, the researchers estimated it would cost approximately $6.9 billion all track mileage. To verify the quality of estimated values, the researchers investigated two recent studies conducted by departments of transportation and determined that the numbers were equitable; A certain degree of variance between the different studies was deemed acceptable due to differences in replacement standards, labor costs, and the condition of the replacement materials.

As shown by the described research studies, the total expenditure needed to completely upgrade Class III railroads throughout the United States is a considerable cost that no private railroad could feasibly afford based solely on annual operating costs. Additionally, as discussed in the literature review, the actual economic benefits of improving sections of Class III rail track structures with light traffic may not justify the funding needed for such an improvement.

2.5 Financial Support for Class III

As of 2017 several sections of Class III railroads in Kansas do not produce enough revenue to justify upgrading track beyond general maintenance for current operations even though the potential increase of traffic allowed by the upgrade would justify the investment. For Class III railroads in such a situation, bank loans, federal and state funding sources, and larger railroads that trade with Class III could be beneficial sources of funding, as explained in the next sections.

2.5.1 Bank Funding

A study conducted by the FRA in 1993 found that Class III railroads, although creditworthy companies, had difficulty obtaining financing for track structure upgrades because a limited number of financial institutions specialized in Class III railroad loans (FRA, 1993). In addition, the scarcity of public information about Class III railroads limited financial institutions' knowledge on which to base risk assessment, and the minimum required amount of $5 million for Class III railroad loans for small projects often prevents ready financing. Lack of interest by financial institutions to increase loan availability for Class III railroads and a certain degree of unwillingness by financial institutions to offer loans for non-liquid assets such as track structure and bridges/structures also hinder the acquisition of financing for Class III railroads.

In 2002 Bitzan et al. investigated six large financial institutions that specialized in railroad financing to determine if the previous conditions still influenced the lending market. Survey results showed that a limited number of financial institutions specialized in financing Class III railroads and that public information on which credit lines could be based was still sparse. Additionally, these institutions were still unwilling to offer loans for track and bridge repairs since those structures are not able to be readily liquidated. However, all surveyed financial institutions indicated they were interested in providing more loans to Class III railroads despite a historic lack of lending (Bitzan et al., 2002).

2.5.2 Federal and State Funding

A variety of federal and state financing programs have been created as alternatives to private financial institutions for financing Class III railroad track and bridge structure rehabilitation projects. These programs, still active in 2017, assist in the continued growth of Class IIIs as the railroads play a key role in the movement of goods to Class I railroads (FRA 2014).

Railroad Rehabilitation and Improvement Financing

The largest federally funded rail program, Railroad Rehabilitation and Improvement Financing (RRIF), is administered by the FRA. Since its initiation the program has provided nearly $2.7 billion in loans to railroads, with 80 percent of the loans directly pertaining to Class II and III railroads. This program allows for improvement or rehabilitation of infrastructure and rail equipment but not operating expenses. The loan ceiling is currently $35 billion, with $7 billion reserved for non-Class I railroads, and the maximum loan term for RRIF is 35 years. As of May 2015, 35 loans were provided throughout 27 states (FRA, 2015; Sage et al., 2015).

Transportation Investment Generating Economic Recovery Grants

The American Recovery and Reinvestment Act of 2009 (ARRA) and the Transportation Investment Generating Economic Recovery (TIGER) (a supplementary discretionary grant program included in ARRA) provided the United States Department of Transportation (USDOT) funding for discretionary grants towards capital investment in the nation’s surface transportation infrastructure, including transit, planning, port, road, and bicycle/pedestrian projects (FRA, 2014). The railroad industry has received approximately $1 billion from TIGER grants, primarily for capacity enhancements, track improvements, and bridge repairs.

TIGER grants also leverage other funding sources. For example, for Class III projects, the funding match comes from the railroad company and/or state and/or local jurisdiction. Then federal, state, and private contributions construct a public private partnership (PPP) that promises to deliver public benefits for which the public pays at least part and private benefits for which the Class III railroad pays. TIGER grants are highly competitive, resulting in a small percentage of all submitted projects being funded (FRA, 2014; Sage et al., 2015). Two Class III railroads in Kansas have received this grant for rail infrastructure improvement: KYLE and South Kansas & Oklahoma).

Railroad Track Maintenance Tax Credit (26 U.S.C. 45G)

The United States allows a tax credit of up to 50 percent from railroad maintenance projects for Class II and Class III railroads to improve infrastructure, including maintaining tracks, roadbeds, bridges, and related structures underneath the regulation of 26 U.S.C. 45G. This credit is capped at $3,500 per mile ($2,190 per km) of track structure the railroad owns or leases. Per the American Class III Railroad Association (ASLRA), more than $300 million worth of Class III infrastructure improvements are assisted by this tax credit each year (FRA, 2014; Sage et al., 2015).

Several states' departments of transportation have recognized the economic benefits of Class III railroads because they link local producers and manufacturers to the national Class I rail network. Therefore, states have provided funding options and tax benefits specifically designed to support local Class III railroads.

Annual Revolving Loans

Annual revolving loans and grant programs capitalized with annual appropriations are overseen by the Secretary of Transportation if the financing is federal and managed by local departments of transportation if the financing is state funded. These programs assist railroad companies by providing matching funds for loan terms of up to 10 years. Interest paid on these loans helps fund additional projects through additional loans. Applicants compete for funding, and recipients can use the funding for state businesses, community industrial parks, and Class III railroads. States currently offering such programs include Idaho, Kansas, New Jersey, New York, Ohio, Oregon, Pennsylvania, Virginia, and Wisconsin (FRA, 2014).

Tax Benefits

Some states recognize Class I and Class III railroads' contributions to economic growth by providing the railroads with additional tax benefits. Connecticut, North Carolina, and Pennsylvania impose statewide gross earnings or receipt taxes on railroads rather than property tax. Massachusetts and New Jersey require only minimal property tax from railroads. New York and Virginia provide railroad property tax relief using an individual classification rule: They inventory each item of taxable property and value it separately regardless of any cooperative effect on the railroad's other properties (FRA, 2014).

2.5.3 Class I Funding

Class I railroads have recently begun collaborating with Class II and Class III railroads to make capital improvements. This collaboration typically occurs when a Class I railroad business is expected to improve due to the rehabilitation of the Class III's asset. Such situations could include extensive disrepair to the Class III's track structure so that it slows down the line or strategic locations of the track for access to a regional freight market. Previous joint ventures have allowed the preservation and rehabilitation of rail lines for public benefit while reducing Class III industry's reliance on financial support from federal or state governments. Corporate partnerships have been shown to increase competition in some regional freight markets (FRA, 2014).

2.6 Overview of Railroad Ballast

Most railroad track is comprised of four major structural components: rails, sleepers, subgrade and ballast as illustrated by Figure 2.1. Most rails installed today are hot rolled steel segments shaped like rounded I-beams differentiated by pounds per yard (lb/yd), usually ranging from 85 to 135 lb/yd (42 to 67 kg/m), depending on the expected traffic of the railroad. Sleepers are slabs made of either treated wood or pre-stressed concrete. The subgrade is the layer of soil supporting the track which typically is compacted and treated to provide adequate support as needed. Ballast is the free draining usually granular material supporting the track structure (Selig and Waters, 1994). Ballast performs many vital functions for the track structure, which includes:

- allowing immediate drainage of surface water,
- resisting vertical, lateral, and longitudinal forces applied to the sleepers to hold the track in place,
- providing a certain degree of resileincy and energy absorption,
- facilitating surfacing and adjustment of track geometry tamping maintanence operations, and
- `reducing pressure from the sleeper bearing area to accptable stress levels for the subgrade.

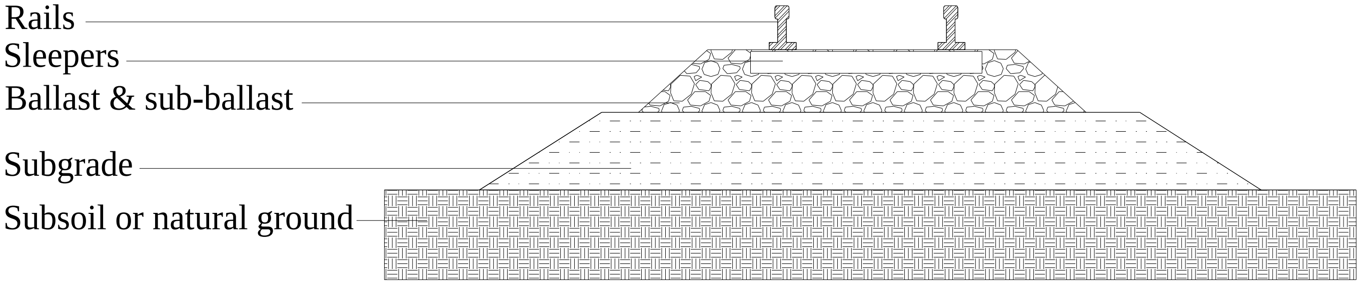


Figure 2.1Diagram of a Typical Track Section (Modified from Selig and Waters, 1994)

As track ages, small particles can fill the voids of the the ballast, which is a process known as fouling. The fine particles can originate from surface pollutants, aggregate degradation, vertical infiltration from subgrade, and sleeper wear (Selig and Waters, 1994). The sources of ballast fouling in North America are shown in Figure 2.2. Three-quarters of fouling is caused by aggregate degradation due to abrasion caused by cyclic trainloads.

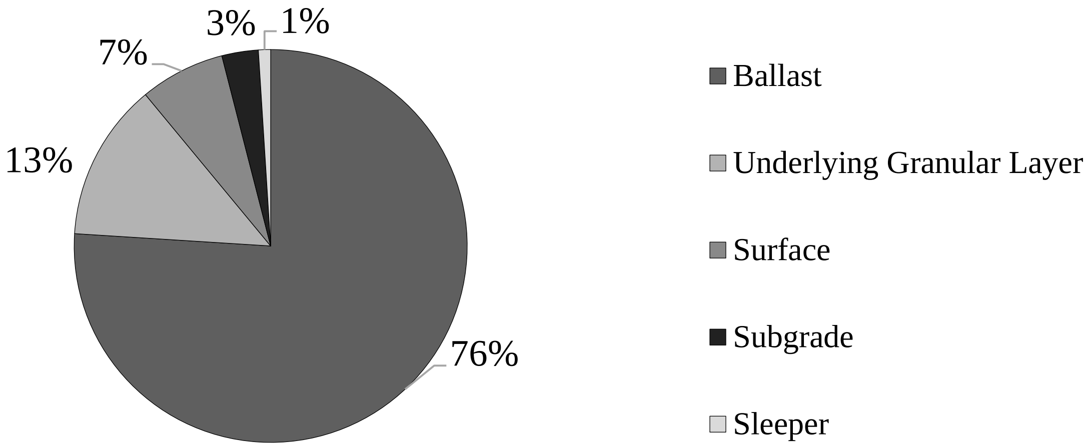


Figure 2.2 Sources of Ballast Fouling (Selig and Waters, 1994

In North America, the amount of fouling is determined by the material's fouling index (FI) which is calculated by

$$FI = P_4 + P_{200} \tag{2.1}$$

where P_4 and P_{200} are the weight percentage of fine particles passing the number 4 (4.75 mm) and 200 (0.075 mm) sieves, respectively. Table 2.4 shows the category of fouled ballast based on the fouling index. Clean ballast has an FI less than one, while highly fouled ballast has an FI larger than 40. The presence of fouling can prevent ballast from fulfilling its primary functions previously noted. The specific effect of fouling on the track structure depends on the characteristics and amounts of fouling agents (Selig and Waters, 1994).

Table 2.4 Levels of Fouling Based on Fouling Index (Selig and Waters, 1994)

Fouling Category	Fouling Index (FI)
Clean	<1
Moderately Clean	1<10
Moderately Fouled	10<20
Fouled	20<40
Highly Fouled	≥40

Sand and small gravel-sized particles will provide increased shear strength and stiffness of ballast, consequently adding more stability and resistance to the structure. Increased fouling will only add to the stability of the track structure as long as the ballast still contains primarily larger coarse particles. The resiliency and drainage capacity are reduced while surfacing and lining operations become more difficult as the void space is filled with sand and gravel. If most of the fouling is from sand or fine gravel, the increase in maintenance cost is generally minimal, and mechanical screening is typically sufficient for cleaning the ballast (Selig and Waters, 1994).

Fouling from clay and silt particles will decrease the drainage capacity of the structure while increasing the rate of aggregate deterioration. The slower drainage can cause water damage including hydraulic erosion, subgrade attrition, and loss of stability. At the highest levels of fine particle fouling, the fines will control the behavior of the ballast, making it difficult for the ballast to hold the other components of the track in place, which is one of ballasts most important jobs. Tamping (compaction of the ballast to increase the durability and strength of the track) will become ineffective with high levels of fine particle fouling. Fine grained particle fouling also increases maintenance costs since simple ballast screening is not effective. Full replacement of the ballast may be necessary if a section of track is highly fouled by clay or silt.

2.7 Detection of Fouled Ballast

Railroad companies must perform routine inspections to ensure that their tracks operate safely and efficiently. During these inspections, data detailing the geometry of the track and condition of the rail, ties, connections and ballast are collected. Often for the condition of the ballast, these data include the depth and degree of fouling. Established methods for determining the fouling of a section of ballast include track coring, trial pits, and excavation (Eriksen et al., 2006). However, these methods are destructive tests and usually require the railroad to restrict or reroute traffic on its network.

Numerous researchers have tested various nondestructive testing methods to determine their feasibility to detect differences between fouled and clean ballast. Electrical resistivity, infrared imaging, multichannel analysis of surface waves (MASW), and GPR are among the nondestructive testing methods that researchers have attempted to correlate to ballast fouling. The benefit of using nondestructive investigations is the ability to continue rail operations during testing and not having to destroy the track or replace the samples collected for testing (Eriksen et al., 2006).

Rahman (2013) and Neupane (2015) investigated the feasibility and refined the methodology of implementing electrical resistivity to determine the level of ballast fouling. Rahman (2013) determined the resistance of fouled ballast with varying levels of fouling using a four point Wenner survey to verify that fouling changed the resistivity of the ballast. Neupane (2015) designed a portable vertical probe to determine the resistivity of ballast using a three point method. However, this probe must be inserted into the ballast, and therefore still requires the redirection of rail traffic for testing.

Clark et al. (2002) studied the infrared thermographic responses of clean and fouled ballast. The researchers cooled samples of ballast with varying levels of fouling and watched them reheat up to room temperature (68°F (20°C)) over time to compare the different rates of heat transfer, as well as performing a field trial on real track. The research team used infrared cameras to document the change in temperature of the samples over time, which was used to calculate the samples' emissivity values. The laboratory trials showed that fouled ballast transfers heat faster than clean ballast. The field tests determined that it is possible to use the infrared thermographic response of the ballast to identify areas with fouled ballast within clean ballast, however such surveys must be performed coinciding with a large change in atmospheric temperature.

Anabazhagan et al. (2011) studied the viability detecting fouled ballast using GPR and MASW. The research team constructed a full-scale model railway track with nine sections of ballast, each with varying levels and types of fouling. A MASW system with 24 channels with 12 geophones of 10 Hz capacity were used to record the seismic waves created by the impulse of a 2.2 lb (1 kg) sledgehammer. The shear wave velocity for the samples were calculated. It was found that the shear wave velocity of clean ballast increased when fouling materials were added up to a certain degree of fouling (about FI = 15) and after that the shear wave velocity of the fouled ballast was lower than the clean ballast. Anabazhagan et al. also used the same model track to investigate the effect of fouling on GPR responses using antennas with a variety of frequencies. They found that the MASW method was better at identifying the type of fouling, while GPR surveys were better at identifying fouled layers. Due to GPR's history of providing high quality data for past researchers, the current use of GPR by the rail industry, and its capacity to be integrated into routine track inspections, GPR was used for this experiment. Therefore, the remaining review of literature will focus on the fundamentals of GPR and provide an overview of previous research that looked into correlating GPR surveys to the condition of railroad ballast.

2.7.1 Fundamentals of Ground Penetrating Radar

GPR is a nondestructive geophysical subsurface imaging survey with a wide variety of geologic and engineering applications. Researchers who have investigated the feasibility of implementing GPR for a variety of purposes. Lunt et al. (2005) estimated the volumetric water content of a Californian winery to determine the effectiveness of its agricultural irrigation. They showed that GPR has the potential to monitor soil water content over large areas with variable hydrologic conditions, and can be used to estimate the volumetric water content of spot locations if the depth of the scans is known. Kalogeropoulo et al. (2013) investigated using GPR to determine the corrosion of concrete due to deicing salt put on roads during winter. Xiang et al. (2013) located anomalies within a tunnel to detect the possible damage to the structure. Both research teams proved that GPR can easily determine heterogeneous regions in the subsurface.

GPR surveys measure the time required for impulses of electromagnetic (EM) waves to reflect off differing subsurface interfaces. The frequency of these waves typically varies from 10 MHz to 2 GHz depending on the antenna. Lower frequency antennas provide deeper surveys, while higher frequency antennas have shallower scans that provide more details thus allowing detection of smaller objects. A transmitting antenna emits pulses of EM waves into the ground, while a receiving antenna records the amplitudes and times of arrival for the waves reflected off subsurface variations (Everett, 2013). The velocity, v, of the EM waves propagated through a non-magnetic medium like the ground is calculated as

$$v = \frac{c}{\sqrt{\varepsilon_r}} \tag{2.2}$$

where c is the speed of light in a vacuum (3 x 10^8 m/s), and ε_r is the dielectric constant of the medium and is unitless. The dielectric constant, or the relative permittivity, is a dimensionless material property governed by the equation

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} \tag{2.3}$$

where ε is the absolute permittivity of the material in F/m, and ε_0 is the permittivity of a vacuum, or 8.854 x 10^{-12} F/m. Absolute permittivity is a baseline measure of the resistance encountered when creating flow of electric fields through empty space. The absolute permittivity of a material is a measurement of the flow of the electric field that that medium will allow. Larger permittivity values provide more resistance to the formation of electric fields (Annan, 2009). Equation 2.2 can be altered to estimate the dielectric constant of materials with a known depth by

$$\varepsilon_r = \left(\frac{cT}{2d}\right)^2 \tag{2.4}$$

where d is the depth of impulse penetration in meters, T is the two-way travel time in seconds, and the remaining variables have previously been defined (Annan, 2009).

For geologic materials, the dielectric constant is a function of mineralogy, porosity, pore fluids, frequency, geometries, and electrochemical interactions between the rock components (Martinez and Byrnes, 2001). The volumetric water content has empirically been proven to be the strongest determining factor for the permittivity of geologic materials (Everett, 2013). The volumetric water content (θ_W) is calculated by

$$\theta_W = \frac{V_w}{V_s} \tag{2.5}$$

where $V_w$is the volume of water within a sample and V_s is the volume of a soil within a sample (Bilskie, 2001). Gravimetric water content can be converted to volumetric by

$$\theta_W = w * SG \tag{2.6}$$

where w is the gravimetric water content calculated by

$$w = \frac{M_w}{M_s} \tag{2.7}$$

where M_w is the mass of water and M_s is the mass of the soil solids and SG is the bulk specific gravity of the material with a typical range of 2.6-2.9 for geologic material. The empirical equation relationship between the dielectric constant to volumetric water content was correlated by Topp et al. (1980) as

$$\varepsilon_r = 3.03 + 9.3 * \theta_W + 146.0 * \theta_W^2 - 76.7 * \theta_W^3 \tag{2.8}$$

where all the variables have previously been defined.

This primary correlation is due to the large dielectric constant of water (~81) when compared to the range for dry geologic martials (3.0-8.0). Water has one of the largest naturally occurring dielectric constants due to its polarization. Polarized water will align its asymmetric charge distribution in the direction of the electric field as diagrammed in Figure 2.3. The atomic movement due to polarization effects transfers a portion of the GPR wave's potential to kinetic energy. This energy transfer reduces the wave's capacity to propagate through the medium, which is reflected by the relatively large dielectric constants for polar materials (Annan, 2009).

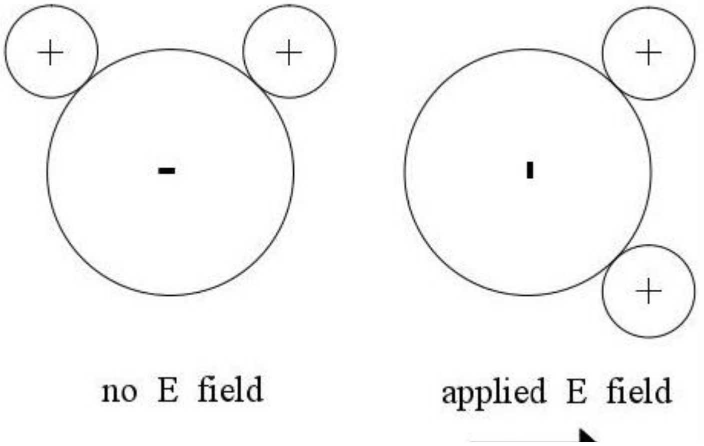


Figure 2.3 Polarization of the Water Molecule

The raw GPR data, or scans, must be processed for geological interpretation. The basic data processing steps include time-zero correction, de-wow filtering, background-removal filtering, and gain control functions. More advanced processing methods and analysis techniques exist, however their utilization is based on the user's preferences, experience, and the nature of the individual dataset (Cassidy, 2009).

Time-zero correction involves shifting the time axis for all individual scans to a recognizable feature common to all scans, usually the first peak of the earliest arriving pulse. This alteration ensures a common time period for the survey entire. Trace misalignments can be caused by drifts in the transmitter or receiver electronics, irregularities in the connector cables between the antenna and the receiver, or small variations in transmitter-receiver antenna spacing and orientation. Time-zero correction improves the spatial coherency of the time sections, improving the data for further processing (Cassidy, 2009).

De-wow low-cut filtering removes the "wow" from the series of scans. "Wow" is any variation or shift in the baseline of amplitude that should ideally be zero at large values of two-way travel times. The main sources for "wow" in data sets are the presence of unwanted low-frequency components in the spectrum of the transmitted electric field and electromagnetic induction effects in the conductive ground. De-wow filters reduces these low frequency components to establish a zero baseline amplitude (Cassidy, 2009).

Background-removal filtering removes a lateral moving average of radar amplitudes over a given early time window from each scan in the survey. This modification removes the presence of ground clutter, or antenna ringing. Ground clutter is high amplitude, laterally continuous signal present in almost every GPR survey caused by direct coupling or cross talk between the transmitting and receiving antennas. Removing the ringing of the antennas from surveys tends to increase visualization of shallow features. However, background-removal filtering might remove a portion of the signal if there is slow changing of elevations and other near surface geological features (Cassidy, 2009).

Gain control functions correct for geometric spreading and attenuation of the wave's propagation through the medium. There are many different types of gain functions, which typically apply a multiplying factor to successive regions of the trace in time. These functions are based on the window length (in ns), selected function (eg. linear or exponential), and the maximum gain allowed. The primary purpose of utilizing a gain functions is to increase visualization shallow and deeper reflections on scans with roughly the same display intensity, which tend to distort with longer window lengths (Cassidy, 2009).

With proper processing, ground penetrating radar data can be useful to a variety of fields. GPR is a relatively simple, rapid tool for nondestructive subsurface investigations. It is able to determine the depth of specialized features, provide an estimate of the water content of soil, and locate subsurface abnormalities.

2.7 Previous GPR Rail Research

Obtaining suitable GPR surveys from railroad tracks is difficult due to interferences from the other sections of the track, especially the metal rail. However, improved GPR technology and altering antenna arrangements have led to improved quality of surveys (Saarenketo, 2009). Many studies have investigating the feasibility of using GPR surveys to characterize the condition of railroad track ballast. Al-Qadi et al. (2009) developed data analysis techniques for GPR assessments of railroad ballast in high radio frequency environments. Al-Qadi et al. (2010) investigated the optimization of multiple-frequency GPR system configurations for railroad substructure assessments. Utilizing the information gained through these studies and many others, GPR surveys have successfully verified track geometry, determined whether the subgrade had mixed with the ballast, and established the dielectric value of the ballast. Table 2.5 shows the dielectric values of clean and fouled ballast at differing moisture contents obtained for two separate investigations. The table shows that water affects the dielectric constant of fouled ballast more than clean ballast. This is due to the larger percentage of fines in the fouled ballast, which hold more water than larger particles (DeBold et al., 2015). The strong GPR response to water content can make determining the level of fouling present in the field difficult due to the tendency of the water to control the GPR scan, rather than any fouling agents.

Table 2.5 Published Dielectric Values of Ballast (Modified from Saarenkento, 2009)

Material	**Dielectric value (Clark, 2001)**	**Dielectric value (Sussman et al. 2002)**
Dry clean ballast	3.0	3.6
Moist clean ballast	3.5	4.0
Wet clean ballast	26.9	n/a
Dry fouled ballast	4.3	3.7
Moist fouled ballast	7.8	5.1
Wet fouled ballast	38.5	7.2

DeBold et al. (2015) analyzed the scattering of the signal’s oscilloscope with respect to the trace’s scan area, axis crossing, and points of inflection for both clean and fouled ballast samples using 900 and 500 MHz frequency antennas. As seen Figure 2.4, data collected from clean ballast had less scattering, with less areas bounded by the individual scans for all antennas. A regression analysis was performed to correlate the fouling index of the ballast to the average area bounded by the traces scan, which is seen in Figure 2.5.

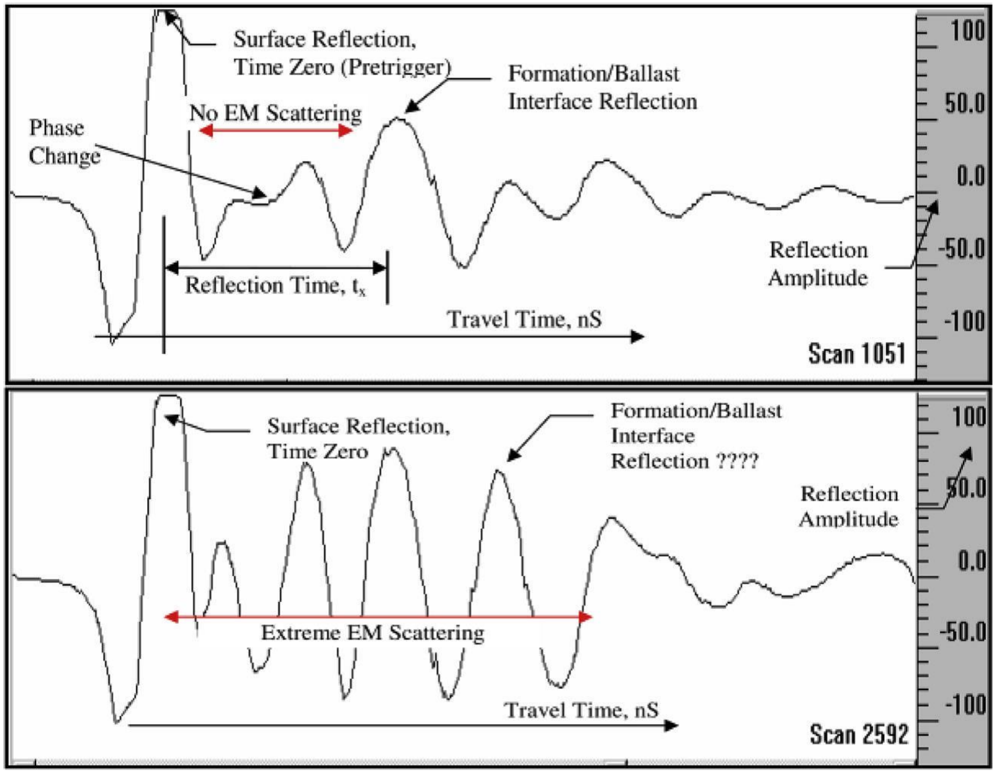


Figure 2.4 Example of 500 MHz Signal Plot through Clean (top) and Fouled (bottom) Ballast (from DeBold et al., 2015)

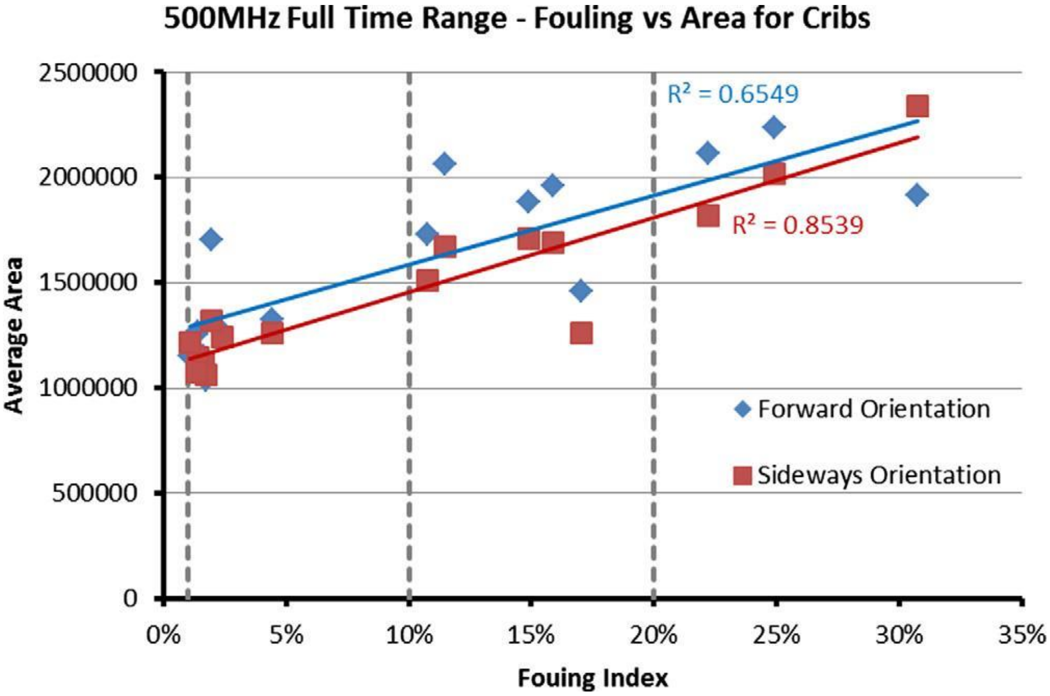


Figure 2.5 500 MHz Correlation Analysis (from DeBold et al., 2015)

The regression curve obtained a coefficient of determination, or the R^2 value, of 0.655 calculated by

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}} \tag{2.9}$$

where SS_{res} is the sum of squares of the residuals, the square area between the data points and the regression line, and $SS_{tot}$is the total sum of squares, the square area between the data points and the mean of the observed data. The closer the coefficient of determination is to one, the better the regression analysis fits the observed data.

Al-Qadi et al. (2010) developed a time-frequency GPR processing technique for ultra-wide bandwidth antennae utilizing a time-frequency GPR data processing method known as a short-time Fourier transform (STFT). The basic concept of this technique is to create a moving average of the amplitudes of sequential scans so that the change in frequency spectrum over time can be determined. The researchers performed this procedure on a large segment of track then collected field samples from test pits at three different sites. A comparison between the FI of the samples and the fouling determined by the STFT processing found that this methodology accurately determines the condition of track ballast (Al-Qadi et al., 2010).

Shangguan and Al-Qadi (2014) continued this branch of research by using laboratory samples to create a content-based image retrieval approach to partially automate the interpretation of railway GPR surveys. They used laboratory samples with varying FI and water contents to create a data base filled with sample GPR surveys of known FI processed using the STFT After that, they created an algorithm to compare collected GPR data to the database to estimate the FI of field surveys. Currently, the database only contains laboratory scans from one type of ballast and fouling agent. This research team is planning on populating their database with datasets of a wide variety of ballast types and fouling agents.

Anbazhagan et al. (2016) investigated the effects of varying fouling agents of GPR surveys. The research team controlled the fouling level for the test materials by mixing measured amounts of coal, iron ore, and screen ballast with clean ballast. Figure 2.6 documents the variance of the calculated dielectric constant with the fouling percentage for each of the fouling agents. This study found that for the same levels of fouling, iron ore increased the dielectric constant more than coal or screen ballast.

Similarly, Sahin (2014) correlated suction and moisture content of roadway base material to the dielectric constant of the material. Base course from 16 varying sites were studied to correlate the dielectric constant to the suction and water content of the samples. Laboratory tests were run to determine the range of dielectric constant and percent of fines for each sample to generate a suction water characteristic curve. A comparison of the calculated to the measured suction, showed that the model could estimate the suction within a coefficient of determination of 0.83. The researchers then collected a 4.5 mile (7.24 km) GPR survey for a section of roadway with known base course material. The dielectric constant for the base course was determined across the length of the survey and used to determine the volumetric water content using the suction water characteristic curves created from the laboratory data. This research shows that GPR surveys are able to determine the water content of the base course of pavements based on the dielectric constant determined by field surveys.

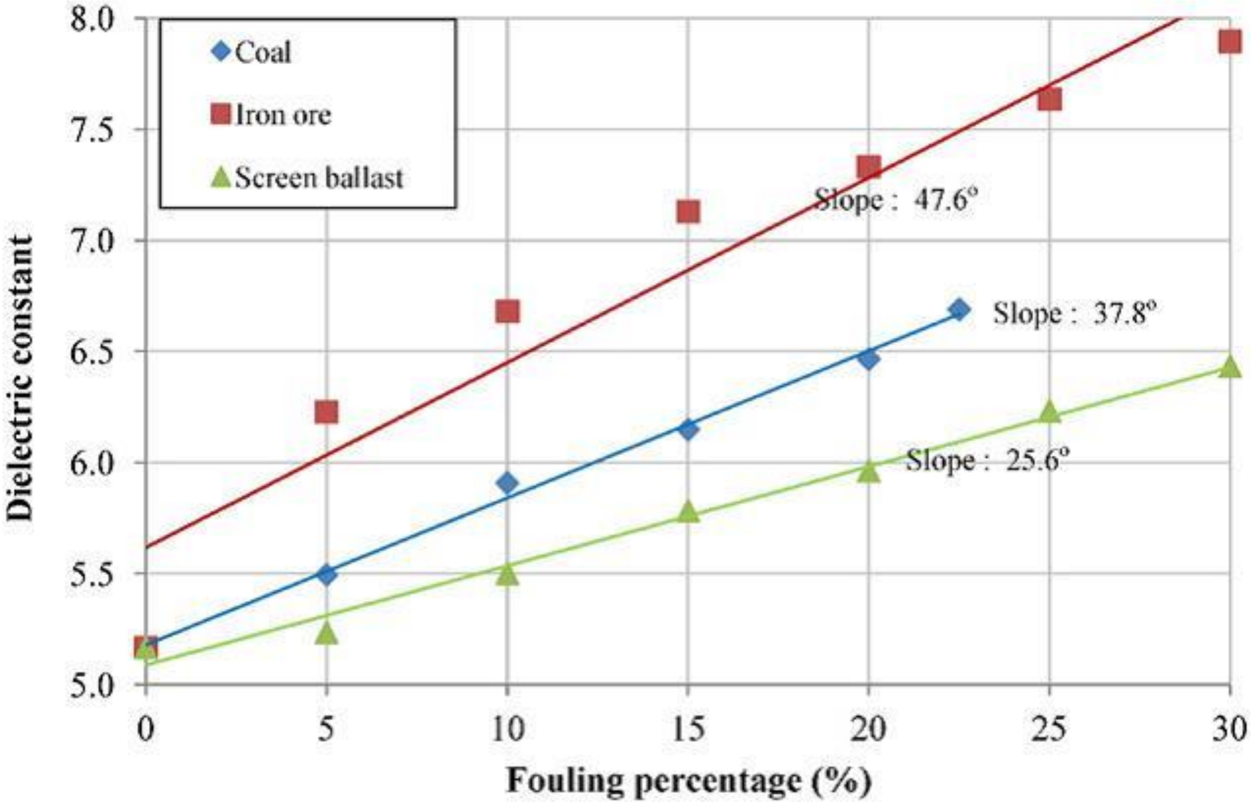


Figure 2.6 Variation of Dielectric Constant with Percentage Fouling for Three Fouling Materials (from Anbazhagan et al., 2016)

Chapter 3 - Methodology

The first objective of this research study was to inventory Class III railroad track structure in Kansas, including critical assessment of the amount of Kansas's railroad system that is compatible with HAL railcars. The predominant commodity and quantity hauled by each Class III railroad were recorded, providing the basis for KDOT-predicted growth in carloads to the network and determining track structure locations for critical upgrades necessary to accommodate HAL railcar service. The following section explains the development, contents, and process of distributing the survey to Class III railroads in Kansas.

The second objective of this study was to establish the feasibility of using GPR to determine the level of fouling by determining the effect of water content on the dielectric constant of clean ballast and sand. The ballast used was rose quartz provided by BNSF railroad. The poorly graded sand was used because of the clean ballast's low water retention. The GPR system used for the study was a 400 MHz antenna with a GSSI TerraSIRch SIR System-3000. The following section explains the development, contents, and process of distributing the survey to the Class III railroads in Kansas and a description of the test setups used for examining the GPR response to clean ballast and sand with differing water contents.

3.1 Class III Railroad Survey

In coordination with KDOT project monitors, the research team at Kansas State University conducted a survey of Class III railroads in Kansas over a six-month period from late 2015 to early 2016. The survey was based on previous studies KDOT and other private consulting firms performed with similar objectives (Sage et al., 2015; Parsons Brinkerhoff, 2005). The survey (included in Appendix A) sought to determine operating and structural characteristics of the railroads, current track inventory, needed upgrades, and scheduled/planned track improvement projects. The survey included the following questions:

1. What are the top five commodities shipped on your railroad?
2. Is your business affected by seasonal differentiation in products? If so explain to what extent.
3. What are your main locations for originating and terminating traffic?
4. Is your railroad owned by a parent company? If so, which one?
5. What are your railroad's primary corridors? Feeder line corridors?
6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? Specifically, subdivision route mileage, gross ton-miles per year, number of slow orders, average number of railcars by weight, total revenue, and percentage non-Class I revenue.
7. What are the infrastructure characteristics of your Class III by subdivision and key segments within the subdivisions? Specifically, the average FRA track class, current operating speed, type of rail, rail weight, rail age, ballast and tie conditions, and weight capacity for each subdivision.
8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?
9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?
10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

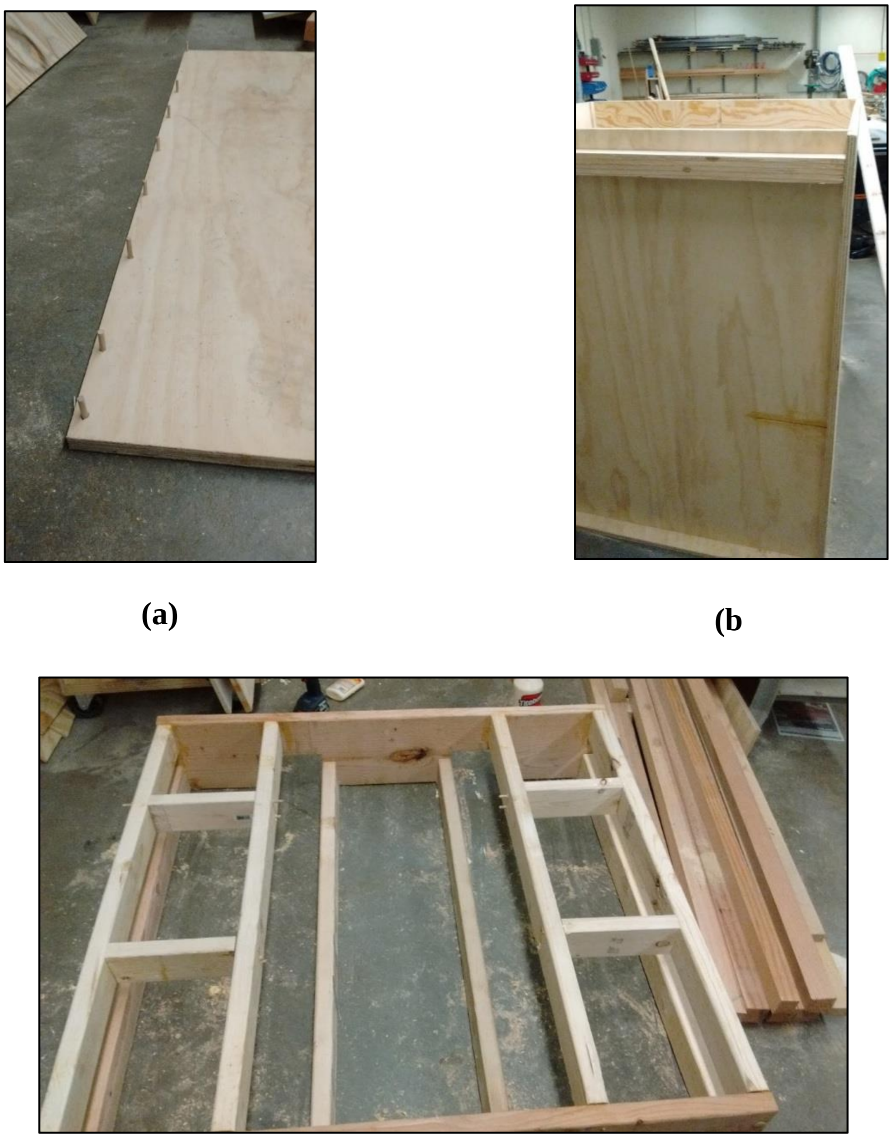
11. Does your company make projections as to future growth in your business? If so, are these by tonnage or number of carloads and what is the basis for these projections? What are your most recent projections for the next three years?
12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?
13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?
14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

Digital surveys were sent to representatives of the Class III railroads operating in Kansas. Prior to sending the official survey, however, verbal and electronic communications were made with each representative to ensure willingness and ability to provide data. The research team also explained the purpose of the study so companies would understand the importance of the information requested. Surveys were sent to 10 out of 13 Class III railroads because KDOT project monitors identified four Class III railroads as having limited route mileage in Kansas, a recent history of low-volume shipping, or less than 10 percent of the total Class III route mileage in Kansas. Data were organized and analyzed in a tiered system to provide guidance for the allocation of funding from the SRSIF.

3.2 Laboratory Setup and Instrumentation

To test the aggregate samples with minimal interference, a test box was designed and constructed. The box was built using 3/4 in (19 mm) plywood, 1/4 in (6.35 mm) diameter wooden dowels, wood glue, scrap lumber, and a plastic drain. One side of the box was removable. A fixed beam across the removable side stabilized the structure from lateral loading of the aggregate. A 3/4 in (19 mm) slot was cut on two sides of the box so that a sectioning bay could be utilized if the box could produce good quality data using half of the footprint. A 4 in (102 mm) drain was cut in the middle to provide the structure a drainage outlet, and a towel was placed over the hole to retain the aggregate within the box. The outside dimensions of the box were 48 x 48 x 48 in (1.2 x 1.2 x 1.2 m). The inside dimensions of each bay was 22.5 x 44.5 x 44.5 in (0.6 x 1.1 x 1.1 m). Figure 3.1(a) shows the setup for using the dowels to fasten the sides together and Figure 3.1 (b) shows the stabilizing beam.

To support the bottom of the box when loaded, and to allow the water to leave the box, a frame was made out scrap wood to raise the structure off the floor. The frame was also specially designed to allow a pallet jack easily lift the box with well-placed notches. The frame is seen in Figure 3.1 (c).



(a)

(b

(c)

Figure 3.1 Test Box Construction a) wooden dowels, b) support bar, c) box support

The depth of ballast chosen for this study was determined by collecting GPR scans with 12, 18, 24, and 30 in (0.306, 0.457, 0.609, and 0.762 m) of ballast in the box which are seen in Figure 3.2 with a line showing the location of the bottom of the box in each of the scans. Since the typical depth of GPR survey looks at the top 14-16 in (0.356-0.406 m), and it was desirable to maximize the amount of ballast surveyed but 30 in (0.762 m) caused excessive lateral support of the test box, 24 in (0.609 m) was selected for the remainder of the ballast tests.

To determine whether the acceptable scans could be collected utilizing only one bay, two sets of data were collected. First, the box was filled using the entire area of the box. Then the bay wall was inserted, and one side of the box was filled to the same height. The scans collected for both of these conditions were very similar, so the sectioning bay was utilized for future tests. The advantage to using the bay was that half of the material could be used, saving the time and energy of transporting the aggregate.

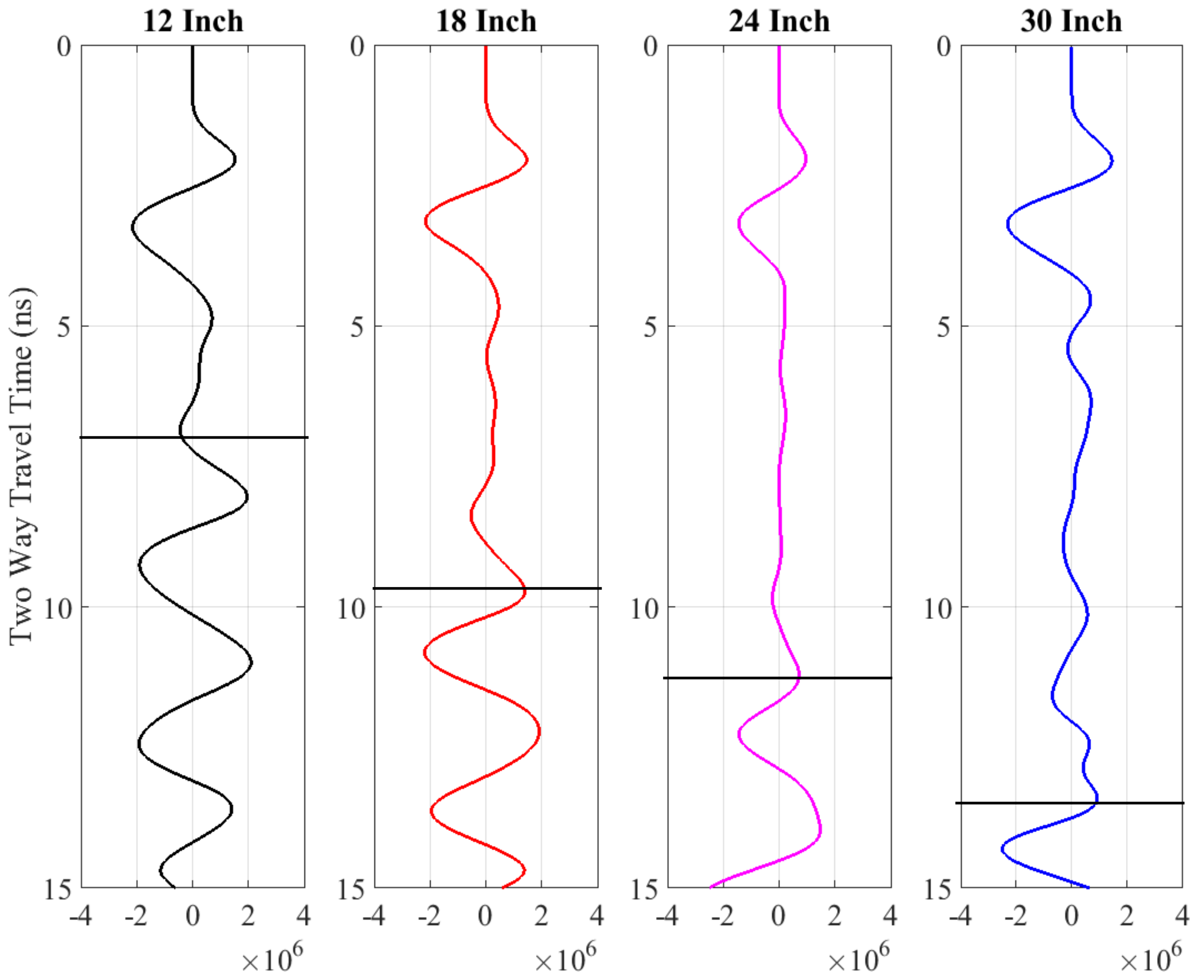


Figure 3.2 Scans for 12, 18, 24, and 30 in (0.306, 0.457, 0.609, and 0.762 m) of Ballast

The next phase of the research was to determine the effect of water on the clean ballast. Six gallons (22.7 L) of water was added to the loaded box using a hand-pump sprayer. GPR readings were collected for every hour for the first eight, and then every twelve hours for the next week. The GPR data were then processed using RADAN (GSSI, 2011). Figure 3.3 shows the GPR antenna on top of both wet and dry ballast.

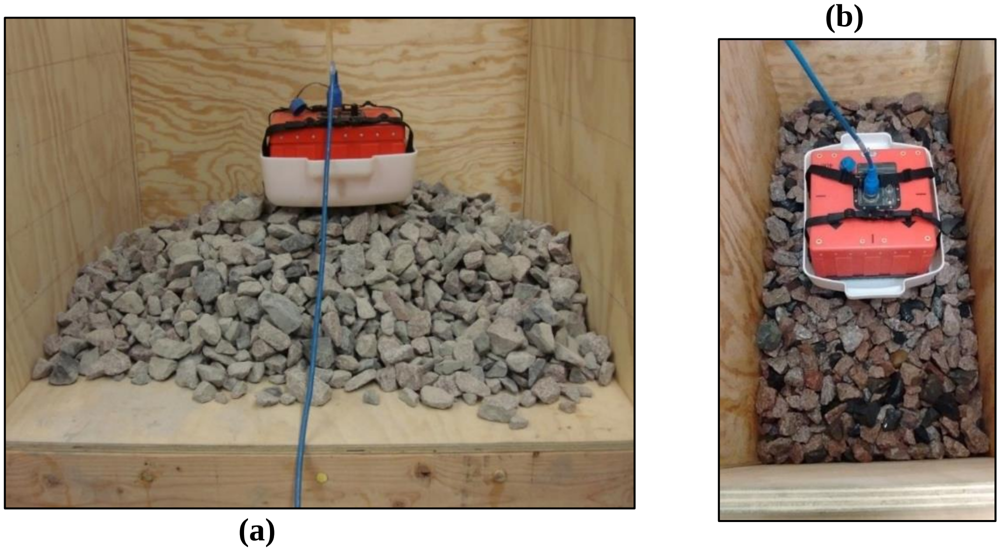


Figure 3.3 Test Set Up for Dry (a) and Wet (b) Clean Ballast

No fouled ballast could be acquired at the time of this testing, therefore further experimentation was conducted using sand. The reasons for switching to sand was that the material was available and able to retain water much better than the clean ballast. A smaller quantity of sand was available, so a smaller test box was used. This box's outer dimensions were 27 x18 x 18 in (0.69 x 0.46 x .046 m) and inner dimensions were 26.5 x17.5 x 17.5 x in (0.67 x 0.44 x 0.44 m) was completely filled with sand. Water was added into the sand one gallon (3.8 L) at a time for ten gallons (38 L). GPR scans were collected after the water was thoroughly mixed with the sand. Samples were taken to determine the water content for each survey.

Chapter 4 - Results

4.1 Class III Carrier Systemwide Inventory

Although Class III railroads in Kansas are as diverse as the communities they serve, recurring themes emerged from the survey data which are summarized in the subsequent sections. The tables in this section categorize Class III railroads as local and regional carriers or switching and terminal carriers. Local and regional railroads tend to have more track miles and haul goods across different regions; switching and terminal railroads typically operate as traditional rail yards in which railcars move within the same city. Results showed that all Class III railroads except one are owned by subsidiaries of parent companies that own and manage a collection of Class III railroads throughout the United States. Table 4.1 specifies the parent company that owns each railroad surveyed in Kansas and summarizes the route mileage of each railroad. As shown in Table 4.1, the length of track operated by Class III railroads varies from 6 miles (10 km) to more than 750 miles (1,200 km).

Table 4.1 Summary of Surveyed Class III Carrier Route Mileages and Parent Companies

Class III Carriers	Route Mileage (km)	Parent Company
Local and Regional Carriers		
Blue Rapids	10 (16)	Georgia-Pacific Gypsum LLC
Boothill & Western	10 (16)	MidWest Pacific Rail
Cimarron Valley	183 (295)	The Western Group, Ogden, UT
Garden City Western	42 (68)	Pioneer Railcorp
Kansas & Oklahoma	642(1,033)	WATCO Co.
KYLE	271 (436)	Genesee & Wyoming Inc.
Missouri & Northern Arkansas	8 (5)	Genesee & Wyoming Inc.
Nebraska, Kansas, & Colorado	68 (109)	OmniTRAX
South Kansas & Oklahoma	267 (430)	WATCO Co.
V&S	21 (34)	Affiliated Railroads
Switching and Terminal Carriers		
Kansas City Terminal (Kaw)	33 (53)	BNSF (track rights) / WATCO Co. (operations)
New Century AirCenter	6 (10)	n/a
Wichita Terminal	9 (15)	BNSF / UP
TOTAL CLASS III	1571 (2,529)	n/a

An important variable for evaluating railroad business effectiveness is the number of railcars that originate and terminate annually. Table 4.2 presents annual carloads by weight and by railroad as reported by Class III railroads in Kansas. As shown in Table 4.2, Class III railroads in Kansas hauled approximately 163,300 carloads of goods based on the data collected. KYLE's carloads were estimated by converting trains to carloads, assuming 25 carloads per train, and Wichita Terminal does not keep record of the weight of the railcars they move. South Kansas & Oklahoma shipped the most total cars, but the Kansas & Oklahoma railroad shipped more than three times the number of 286,000 lb (129,844 kg) carloads than any other railroad. A common estimate found during the survey was that every railcar on Class III railroads in Kansas removes three to four semi-trucks from the highway system, translating to between 468,600 and 624,800 trucks (KDOT, 2011).

Table 4.2 Summary of Surveyed Class III Carrier Carloads by Railcar Weight (2015)

Class III Carriers	**Yearly 263,000 lb (119,295 kg) Carloads**	**Yearly 286,000 lb (129,844 kg) Carloads**	**Total Carloads**
Local and Regional Carriers			
Blue Rapids	400	0	400
Cimarron Valley	6,600	4,400	11,000
Garden City Western	1,200	0	1,200
Kansas & Oklahoma	10,600	32,600	43,200
KYLE	20,000	500	25,000
South Kansas & Oklahoma	51,200	5,700	56,900
V&S	450	450	900
Switching and Terminal Carriers			
Kansas City Terminal	0	16,100	16,100
New Century AirCenter	560	140	700
Wichita Terminal	n/a	n/a	3,750
TOTAL CLASS III	87,010	64,190	156,200

Note: Nebraska, Kansas, & Colorado Railroad, Boothill & Western Railway, and Missouri & Northern Arkansas Railroad were not surveyed.

Railroads often project future growth based on customers and market predictions for the shipped commodities. Table 4.3 details predictions of the surveyed railroads. As shown in Table 4.3 all Class III railroads in Kansas expect growth in future carloads. However, Wichita Terminal did not independently project future carloads since the UP and BNSF railroads have joint ownership and are in charge of marketing projections. Also, KYLE's future projections were not available to the research team or public due to company policy at the time of this research study.

Table 4.3 Summary of Surveyed Class III Carrier Projected Future Carloads

Class III Carrier	**2015**	**2016**	**2017**
Local and Regional Carriers			
Blue Rapids	400	500	500
Cimarron Valley	11,000	12,100	13,310
Garden City Western	1,200	1,375	1,450
Kansas & Oklahoma	42,222	43,222	44,222
KYLE	25,000	n/a	n/a
South Kansas & Oklahoma	62,212	68,643	70,015
V&S	1,000	1,000	1,000
Switching and Terminal Carriers			
Kansas City Terminal	16,100	5,475	5,639
New Century AirCenter	700	1,250	1,750
Wichita Terminal	3,750	n/a	n/a
TOTAL CLASS III	156,200	133,565	137,886

Note: Nebraska, Kansas, & Colorado Railroad, Boothill & Western Railway, and Missouri & Northern Arkansas Railroad were not surveyed.

A track's weight capacity, or the maximum allowable weight the track can safely support, is determined by the interaction of its rail, ballast, and ties. Trained track inspectors can determine the weight capacity of a section of track and identify poor track conditions. The minimum rail weight for a track to accommodate 286,000 lb (129,844 kg) railcars with low risk of derailment or other similar operation issues is 85 lb/yd (42 kg/m), providing that tie condition, ballast depth, and other track material are in acceptable condition (Resor et al., 2000). Table 4.4 to Table 4.6 provide a summary of the track conditions of Class III railroads in Kansas, including the rail weight by mile and the percentage of 286,000 lb (129,844 kg) railcar capacity track versus the percentage of tons from 286,000 lb (129,844 kg) railcars and FRA class track by mile, respectively.

As shown in Table 4.4, based on rail weight, approximately 16 percent of the Class III railroad mileage was not adequate for HAL cars even if the rest of the track was in acceptable condition. In the “Greater than 100 lb/yd (50 kg/m)” category, most of the rail was 115 lb/yd (57 kg/m), with a maximum weight of 136 lb/yd (68 kg/m), demonstrating rail weights that were considerably lighter than 133 and 141 lb/yd (66 and 70 kg/m) Class I railroads currently use for high-speed operations.

Table 4.4 Summary of Surveyed Class III Carrier Rail Weights by Miles

Class III Carrier	**Total**	**70–85 lb/yd (35–42 kg/m)**	**86–99 lb/yd (42–49 kg/m)**	**Greater than 100 lb/yd (50 kg/m)**
Local and Regional Carriers				
Blue Rapids	10	0	10	0
Cimarron Valley	255	0	51	204
Garden City Western	42	38	4	0
Kansas & Oklahoma	759	253	145	361
KYLE	458	0	46	412
South Kansas & Oklahoma	276	1	105	171
V&S	21	0	0	21
Switching and Terminal Carriers				
Kansas City Terminal	21	0	0	21
New Century AirCenter	6	0	3	3
Wichita Terminal	10	0	5	5
TOTAL CLASS III	1,858	291	368	1,198

Note: Nebraska, Kansas, & Colorado Railroad, Boothill & Western Railway, and Missouri & Northern Arkansas Railroad were not surveyed.

Table 4.5 compares surveyed short line railroads with 286,000 lb capacity versus estimated tons shipped using HAL railcars. Table 4.5 shows that, overall, only 30 percent of the entire Class III network in Kansas has been upgraded to accommodate 286,000 lb (129,844 kg) carloads, which account for approximately 37 percent of Class III rail shipments in Kansas.

Table 4.5 Comparison of Surveyed Class III Carrier's 286,000 lb (129,844 kg) Capacity Versus Estimated Tons Shipped Using 286,000 lb (129,844 kg) Railcars

Class III Carrier	Route Mileage	Length 286,000 Capable	Percentage 286,000 lb Capable Track	Percentage Tons from 286,000 lb Cars
Local and Regional Carriers				
Blue Rapids	10	0	0%	0%
Cimarron Valley	255	135	53%	43%
Garden City Western	42	28	67%	0%
Kansas & Oklahoma	759	236	31%	77%
KYLE	458	57	12%	22%
South Kansas & Oklahoma	276	49	18%	11%
V&S	21	21	100%	53%
Switching and Terminal Carriers				
Kansas City Terminal	21	21	100%	100%
New Century AirCenter	6	6	100%	22%
Wichita Terminal	10	10	100%	n/a
TOTAL CLASS III	1,857	563	30%	37%

Note: Nebraska, Kansas, & Colorado Railroad, Boothill & Western Railway, and Missouri & Northern Arkansas Railroad were not surveyed.

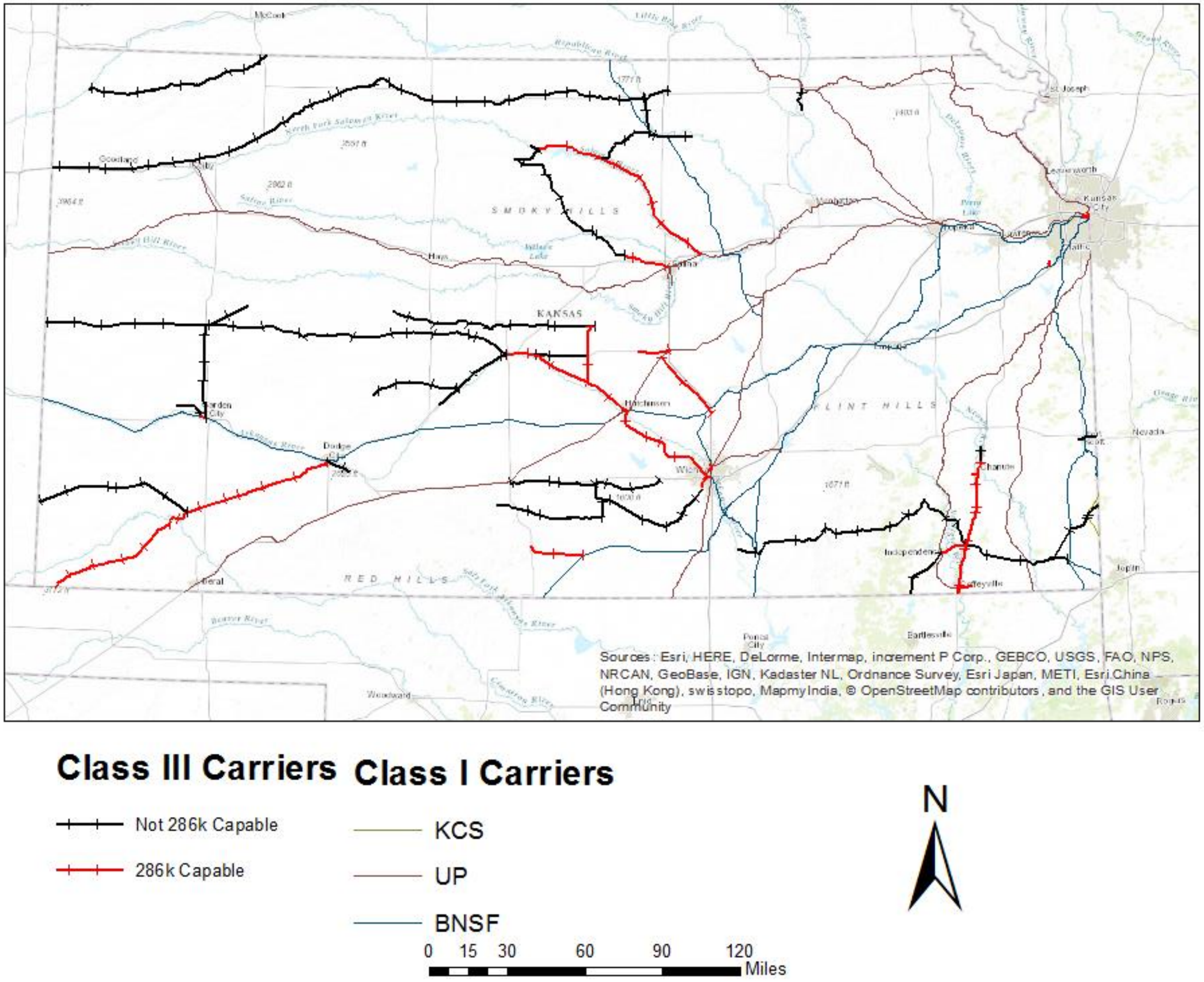
The FRA defines maximum allowable operating speed limits of trains based on the track condition, and track conditions are divided into classes based on strict track structure parameters. The Excepted class is the lowest quality of track allowed and requires freight trains to travel below 10 mph (16 kmh). Class 1, Class 2, Class 3, Class 4, and Class 5 have maximum allowable freight operating speeds of 10, 25, 40, 60, and 80 mph (16, 40, 64, 97, and 129 kmh), respectively. Table 4.6 classifies the total mileage as each FRA track for Class III railroads in Kansas.

Table 4.6 Summary of Surveyed Class III Carrier FRA Track Class by Mile

Class III Carrier	**Total**	**Excepted**	**Class 1 (10 mph)**	**Class 2 (25 mph)**	**Class 3 (40 mph)**
Local and Regional Carriers					
Blue Rapids	10	10	0	0	0
Boothill & Western	10	0	10	0	0
Cimarron Valley	255	0	255	0	0
Garden City Western	42	0	42	0	0
Kansas & Oklahoma	759	45	352	362	0
KYLE	458	0	72	149	237
Missouri & Northern Arkansas	8	8	0	0	0
Nebraska, Kansas, & Colorado	68	68	0	0	0
South Kansas & Oklahoma	276	0	164	112	0
V&S	21	21	0	0	0
Switching and Terminal Carriers					
Kansas City Terminal	21	0	21	0	0
New Century AirCenter	6	0	6	0	0
Wichita Terminal	10	0	10	0	0
TOTAL CLASS III	1,944	152	932	623	237

As shown in Table 4.6, approximately half of all Class III railroads in Kansas are restricted to speeds of 10 mph (16 kmh) or less. Although the KYLE, Kansas & Oklahoma, and South Kansas & Oklahoma railroads have long stretches of track that are Class 2 and above, many sections of those tracks may still operate at slower speeds due to safety concerns such as derailment. For sections of track hundreds of miles long with a lower class, speed restrictions can slow operations, decrease operating efficiencies, increase fuel consumption, and hinder customer service due to the distance the train must travel and FRA restrictions mandating 12 hours as the maximum number of consecutive hours an employee can work (Federal Register, 2008).

Figure 4.1 illustrates where Class III railroads with 286,000 lb (129,844 kg) railcar compatible tracks are located in Kansas. Red segments on the map signify that the track can accommodate 286,000 lb (129,844) railcars; black segments cannot accommodate railcars of that weight. In addition to locations of compatible track, the figure also shows where short line railroads connect to Class I railroads.



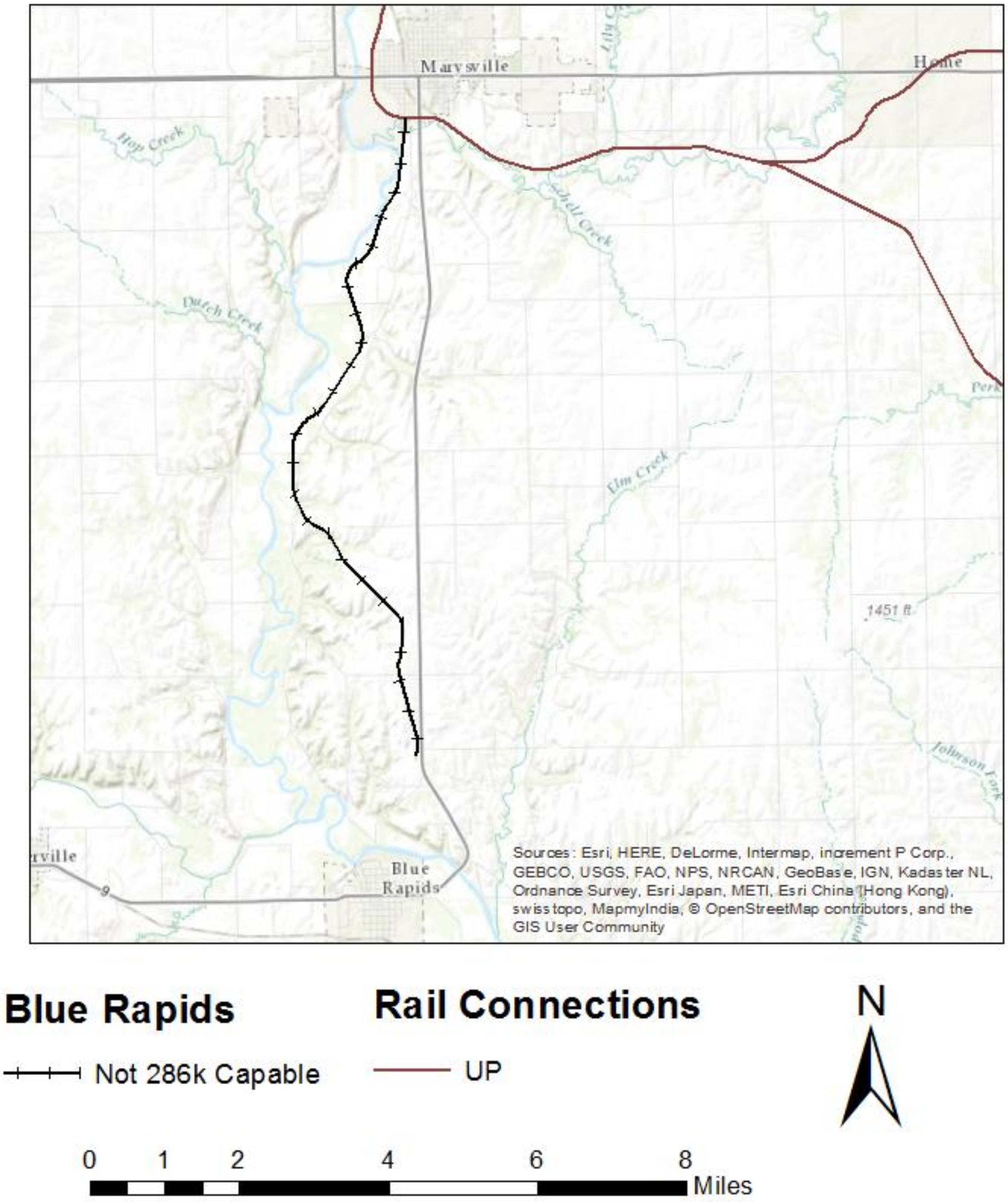
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.1 Active Freight Railroads in Kansas by Weight Capacity (2017)

4.2 Individual Class III Railroad Inventory

4.2.1 Blue Rapids Railroad

The Blue Rapids Railroad (BRRR) is a 10-mile (16 km) segment of track connecting Georgia Pacific Gypsum LLC's manufacturing facility in Blue Rapids, Kansas, to UP railroad lines. Since the mid-1980's Georgia Pacific has used railcars to transport industrial gypsum plaster from their plant to the UP railyard in Marysville, Kansas. The company relies on UP for twice-weekly switching operations. In 2015 BRRR hauled approximately 500 carloads weighing 263,000 lb (119,295 kg). Survey results showed that no track segments could accommodate 286,000 lb (129,844 kg) railcars and that the company does not intend to increase track capacity. Figure 4.2 shows the weight capacity of the BRRR.

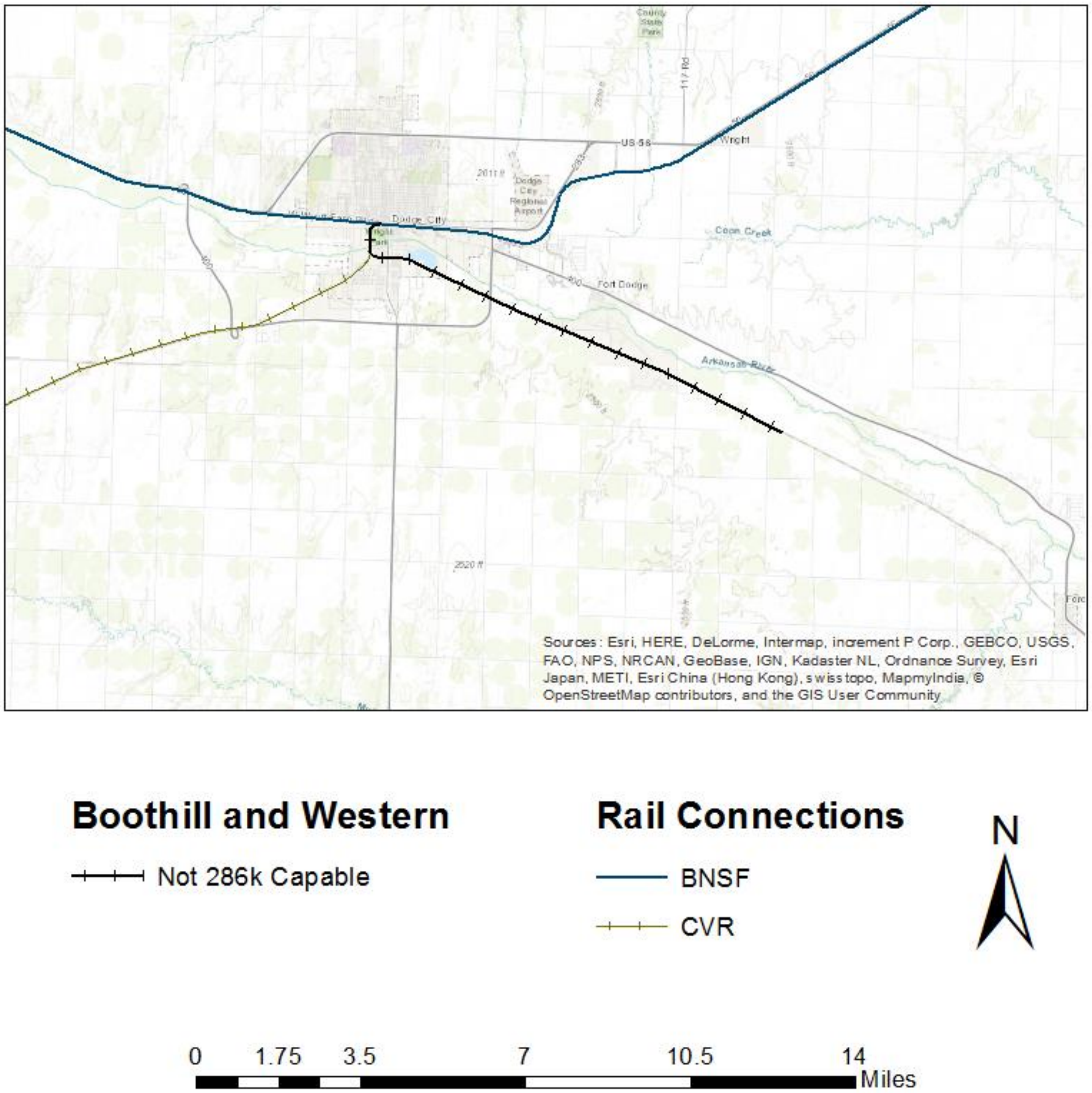


Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.2 Weight Capacity Map for the Blue Rapids Railroad

4.2.2 Boothill and Western Railway

The Boothill & Western (BH&W) railway is a 10-mile (16 km) stretch of track that connects Dodge City, Kansas to Bucklin, Kansas. BH&W was created from the former Chicago, Rock Island and Pacific Railroad. BH&W currently only generates revenue from car storage fees. Figure 4.3 shows the weight capacity of the BH&W railway.

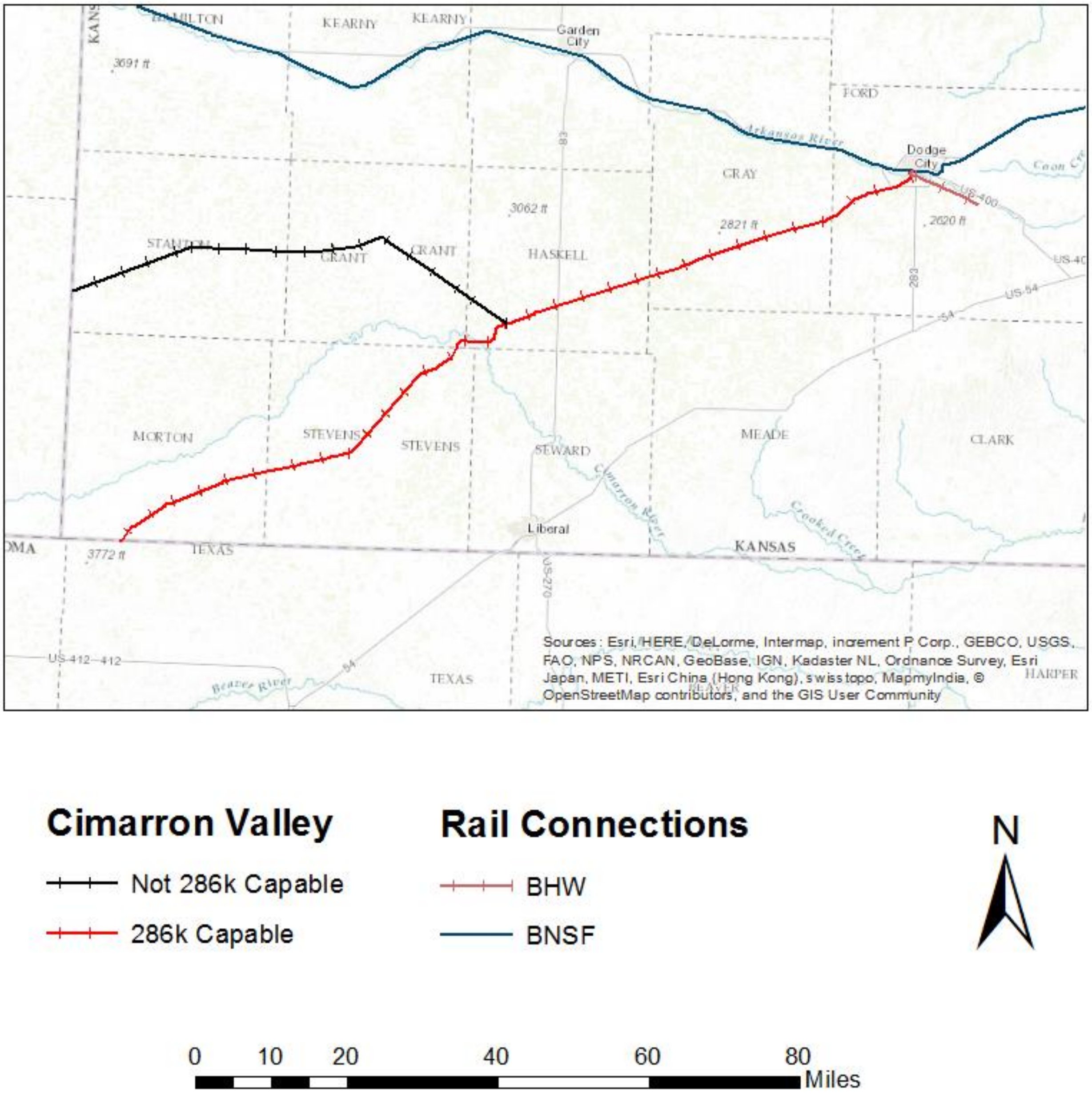


Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.3 Weight Capacity Map for the Boothill & Western Railway

4.2.3 Cimarron Valley Railroad

The Cimarron Valley Railroad (CVR) is a subsidiary of the Western Group. CVR operates a total of 255 miles (410 km) of track, of which approximately 183 miles (294 km) are located in Kansas. The primary agricultural commodities shipped by CVR include wheat, milo, soybean meal, corn, and fuel oil. CVR runs from Dodge City, Kansas, to Satanta, Kansas, where it splits into two lines. The western route continues to Springfield, Colorado, and the southern route continues to Boise City, Oklahoma. The southern route was reported to be able to accommodate 286,000 lb (129,844 kg) railcars, while the western route cannot. According to the survey, CVR currently has no plans to upgrade the weight capacity of the western route. As reported, CVR transported six thousand 263,000 lb (119,295) and forty-four hundred 286,000 lb (129,844 kg) carloads in 2015. Figure 4.4 details the weight capacity of CVR.



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.4 Weight Capacity for the Cimarron Valley Railroad

4.2.4 Garden City Western Railway

The Garden City Western (GCW) railway is a wholly-owned subsidiary of Pioneer Railcorp. GCW consists of a 40-mile (64) track segment serving the southwestern part of Kansas near Garden City, Kansas. The primary commodities hauled by GCW include fertilizers, meal, scrap metal, molasses, and utility poles. GCW recently upgraded three miles of their main line and 13 yard switches to accommodate 286,000 lb (129,844 kg) railcars. Survey results showed that 286,000 lb (129,844 kg) railcars account for 95 percent of all inbound and outbound traffic for the railroad. In 2015 GCW transported 14 hundred 263,000 lb (119,295 kg) railcars. Figure 4.5 illustrates the weight capacity of the GCW railway.

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.5 Weight Capacity Map for the Garden City Western Railway

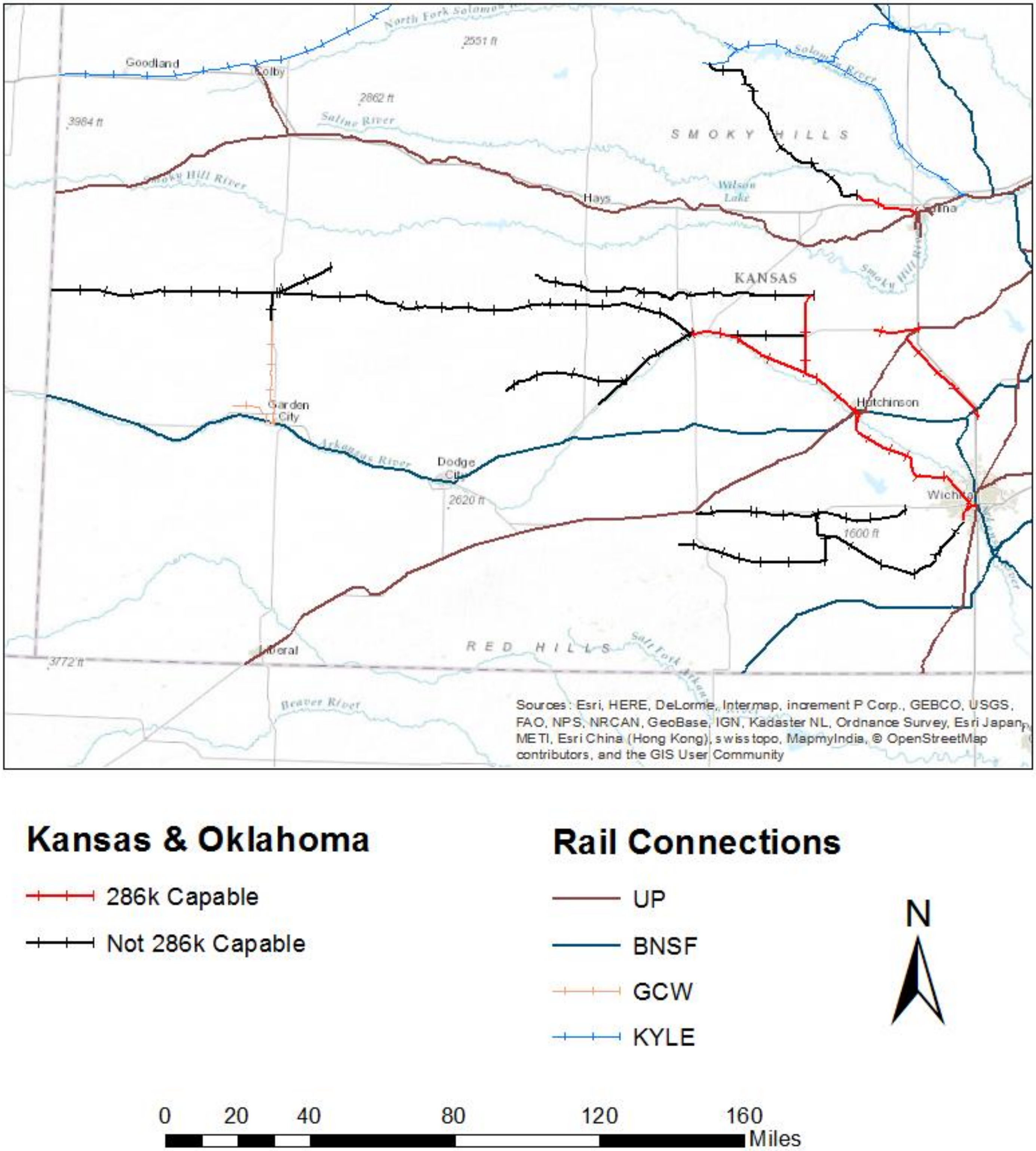
4.2.5 Kansas and Oklahoma Railroad

The Kansas & Oklahoma Railroad (KO) is a subsidiary of WATCO Companies Inc., a Class III railroad-holding company headquartered in Pittsburg, Kansas. KO hauls commodities such as wheat, sorghum, rains, fertilizers, and soybean meals, as well as Class 8 corrosive materials, paper, and flammable gases. KO, one of the largest Class III railroads in North America, operates approximately 766 track miles (1,232 km) that stretch in three directions from Wichita, Kansas. Table 4.7 summarizes the carloads and weight capacity for sections of the KO.

Table 4.7 Summary of Kansas & Oklahoma Data by Rail Corridor

Section	Route Mileage	Mileage 286,000 lb Capable	Percentage Track 286,000 lb Capable	Yearly 263,000 lb Railcars	Yearly 286,000 lb Railcars	Percentage of Tons from 286,000 lb Cars
Conway Springs	101.3	0	0.0%	2,220	12,600	86.3%
Kingman	60.2	0	0.0%	492	0	0.0%
Hutchison	52.9	52.9	100.0%	0	2,412	100.0%
Great Bend	120	51.2	42.7%	0	4,608	100.0%
Hoisington	104.9	104.9	100.0%	1,692	0	0.0%
Scott City	203.4	0	0.0%	4,980	0	0.0%
McPherson	13.2	5.7	43.2%	0	7,212	100.0%
Newton	27	27	100.0%	0	612	100.0%
Salina	82.7	0	0.0%	1,212	5,160	82.5%
K&O TOTAL:	765.6	241.7	32%	10,596	32,604	77.4%

As shown, the Conway Springs section has no track structure that can accommodate 286,000 lb (129,844 kg) railcars. However, a majority of KO business involves 286,000 lb (129,844) railcars, so the railroad only partially fills the larger cars. Figure 4.6 shows weight capacity of KO track corridors.



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.6 Weight Capacity Map for the Kansas & Oklahoma Railroad

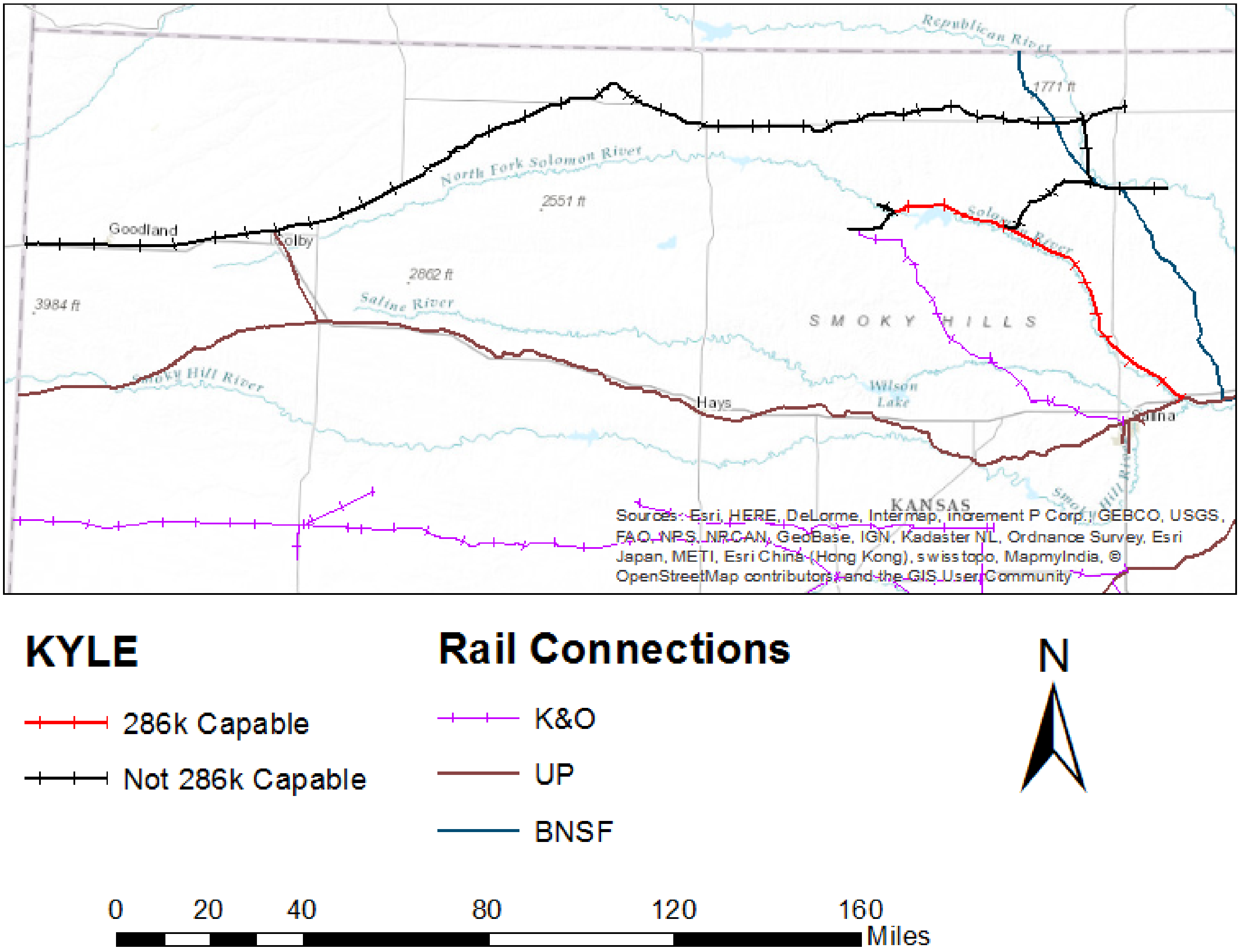
4.2.6 Kyle Railroad

Since 2012 Kyle Railroad (KYLE) has been owned and operated by Genesee & Wyoming Inc., the largest publicly traded Class III holding company in the United States. Prior to ownership by Genesee & Wyoming, the KYLE was owned by Rail America. KYLE operates more than 500 miles (805 km) of track, of which 458 miles (737 km) are located in Kansas and connect to BNSF, UP, and KO railroads, allowing shippers multiple transportation options. KYLE primarily transports winter wheat, sorghum, roofing granules, and corn. Table 4.8 summarizes the carloads and weight capacities for sections of the KYLE.

Table 4.8 Summary of KYLE Data by Rail Corridor

Section	Route Mileage	Mileage 286,000 lb Capable	Percentage Track 286,000 lb Capable	Yearly 263,000 lb Railcars	Yearly 286,000 lb Railcars	Percentage of Tons from 286,000 lb Cars
Solomon	57	57	100.0%	0	90	100.0%
Concordia	53	0	0.0%	72	0	0.0%
Yuma	15	0	0.0%	nominal	0	0.0%
Bellville	96	0	0.0%	72	0	0.0%
Phillipsburg	140	0	0.0%	72	0	0.0%
Goodland	97	0	0.0%	72	0	0.0%
KYLE TOTAL:	458	57	12%	288	90	24.50%

As shown in Table 4.8, the Yuma section segment contains an out-of-service bridge that hinders any shipments utilizing this route. Currently, only the Solomon segment can accommodate 286,000 lb (129,844 kg) railcars; however, as stated in the survey, the KYLE hopes to improve the Bellville and Concordia subdivisions so the Phillipsburg operations and Goodland division can include 286,000 lb (129,844 kg) cars, offering heavier carloads to their grain customers. Figure 4.7 details the weight capacity and rail connections for the KYLE.

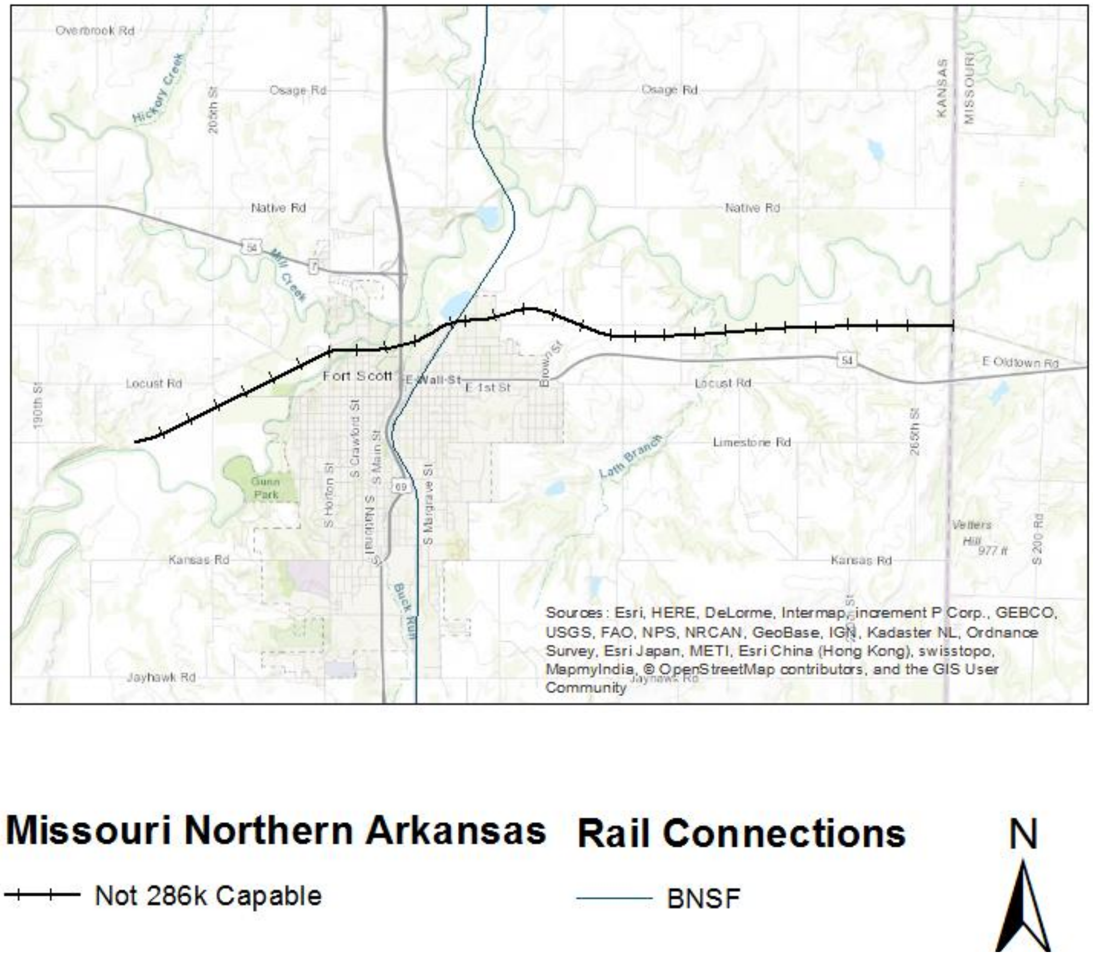


Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.7 Weight Capacity Map for the KYLE Railroad

4.2.7 Missouri & Northern Arkansas

The Kansas portion of the Missouri & Northern Arkansas (M&NA) is an 8-mile segment that connects Fort Scott, Kansas, to Nevada, Missouri. Although the railroad is owned by Genesee & Wyoming Inc., this track segment is leased from UP. While the railroad is currently classified as active, no shipping is occurring on this segment of track. The weight capacity map for M&NA is shown in Figure 4.8.

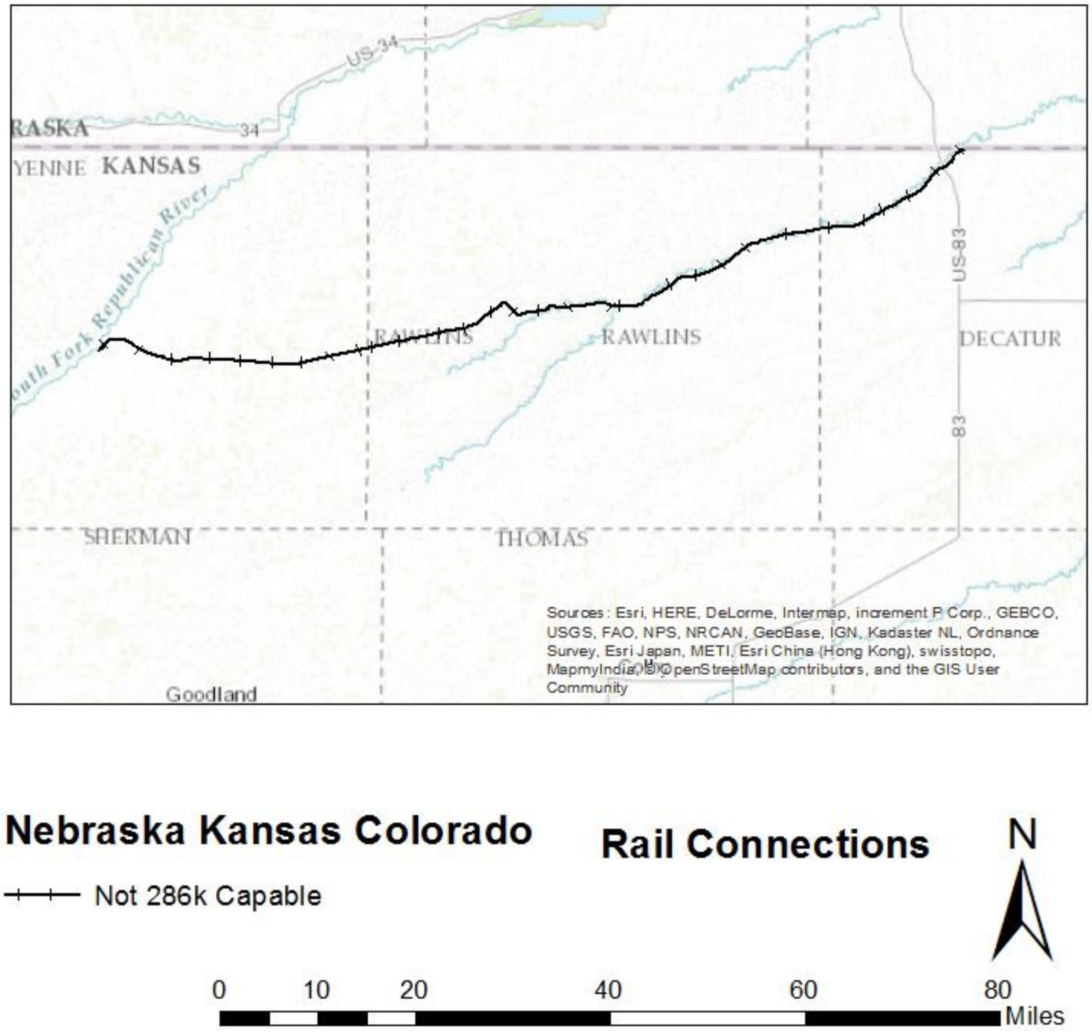


Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.8 Weight Capacity Map for the Missouri & Northern Arkansas Railroad

4.2.8 Nebraska Kansas Colorado Railway

The Nebraska, Kansas, & Colorado Railway, LLC (NKCR) is an 86-mile stretch of track in the northwestern corner of Kanas. This section of rail currently only generates revenue via railcar storage. NKCR previously had two separate subdivisions in Kansas, but the Oberlin subdivision was abandoned, leaving only the St. Francis subdivision. Figure 4.9 shows the weight capacity map for NKCR.



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.9 Weight Capacity Map for the Nebraska, Kansas, & Colorado Railway

4.2.9 South Kansas & Oklahoma Railroad

The South Kansas & Oklahoma (SKOL) railroad, a subsidiary of WATCO, operates nearly 300 miles (482 km) of track in Kansas, originating in Cherryvale, Kansas. SKOL ships commodities such as cement, chemicals, sand, rocks, grains, and grain products. Table 4.9 summarizes shipping and structural data by SKOL subdivision. As shown in the table, SKOL transported over fifty thousand 263,000 lb (119,294 kg) and five thousand five hundred 286,000 lb (129,844) railcars during 2015. Although only the Chanute and Coffeyville portions of the SKOL can currently accommodate 286,000 lb (129,844) carloads. SKOL officials are evaluating track capacity upgrades on the Moline, Chanute, Coffeyville, and Tulsa sections. Figure 4.10 illustrates the weight capacity of the SKOL.

Table 4.9 Summary of South Kansas & Oklahoma Data by Rail Corridor

Section	Route Mileage	Mileage 286,000 lb Capable	Percentage Track 286,000 lb Capable	Yearly 263,000 lb Railcars	Yearly 286,000 lb Railcars	Percentage of Tons from 286,000 lb Cars
Chanute	35.2	35.2	100.0%	5,029	2,263	33.3%
Coffeyville	14	14	100.0%	13,771	2,987	17.8%
Tulsa	15	0	0.0%	8,206	24	0.3%
Neodesha	96	0	0.0%	11,728	635	5.7%
Gorilla	140	0	0.0%	5,176	0	0.0%
Moline	97	0	0.0%	7,430	121	1.8%
SKOL TOTAL:	397.2	49.2	12%	51,339	5,729	16.7%

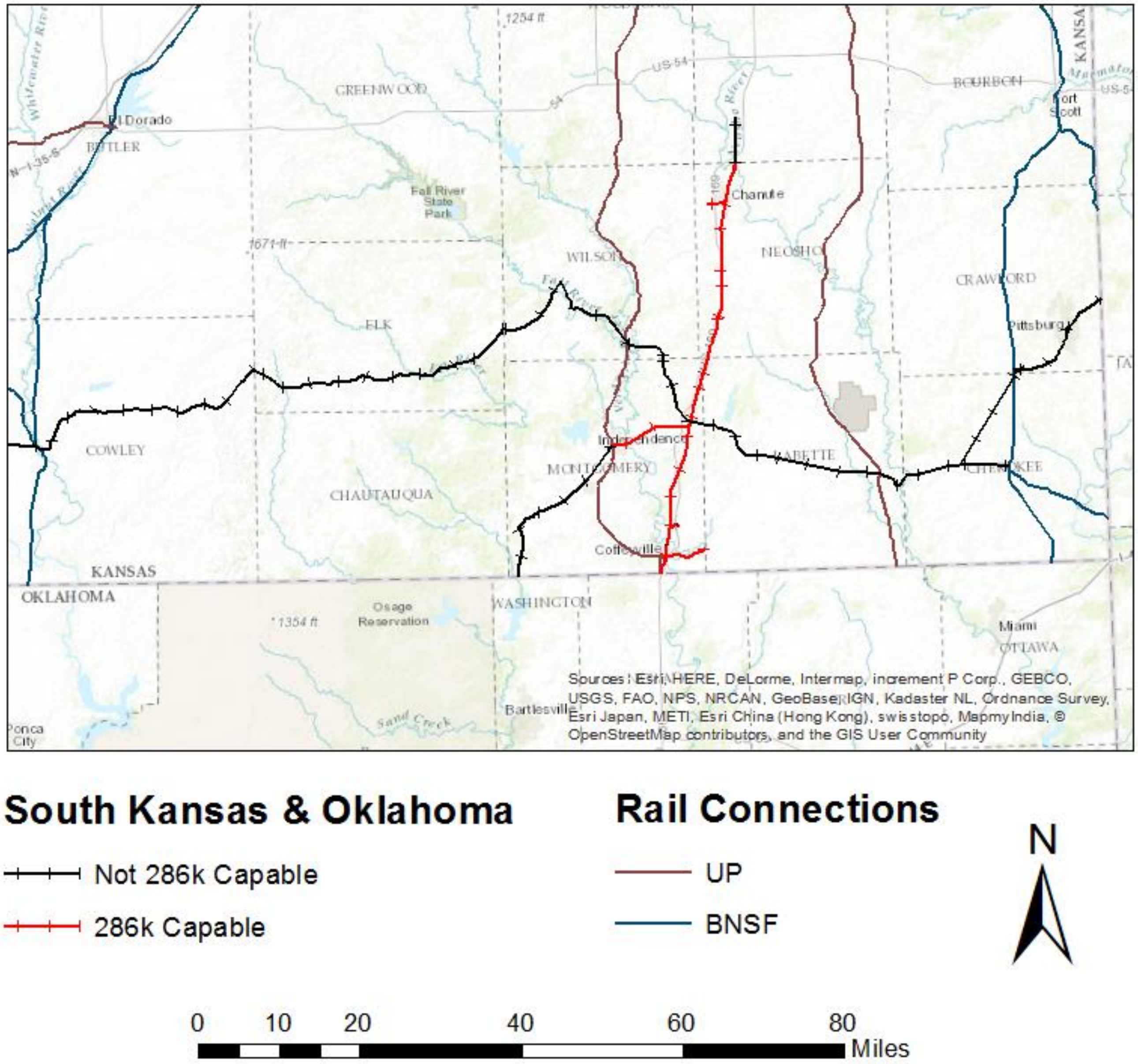


Figure 4.10 Weight Capacity Map for the South Kansas & Oklahoma Railroad

4.2.10 V&S Railway

The V&S Railway (VSR) is a stand-alone company managed by Affiliated Railroads as part of a non-corporate designation with four other Class III railroads. VSR operates two disconnected lines in Kansas consisting of a 22-mile (35 km) segment of track from Medicine Lodge, Kansas, to Attica, Kansas, and a 5-mile (8 km) segment of switching track in Hutchinson, Kansas. VSR transports industrial goods such as wallboards, plaster, scrap metal, and fertilizer from a manufacturing plant in Medicine Lodge, Kansas. All VSR track sections can accommodate 286,000 lb railcars (129,844 kg). The survey indicated that the most pressing issues for VSR is the aging of their bridges and needed funding to repair them. In 2015 VSR transported approximately four hundred and eighty 263,000 lb (119,295 kg) and four hundred and eighty 286,000 lb (129,844 kg) railcars. Figure 4.11 contains a map of the Medicine Lodge subdivision of the VSR.

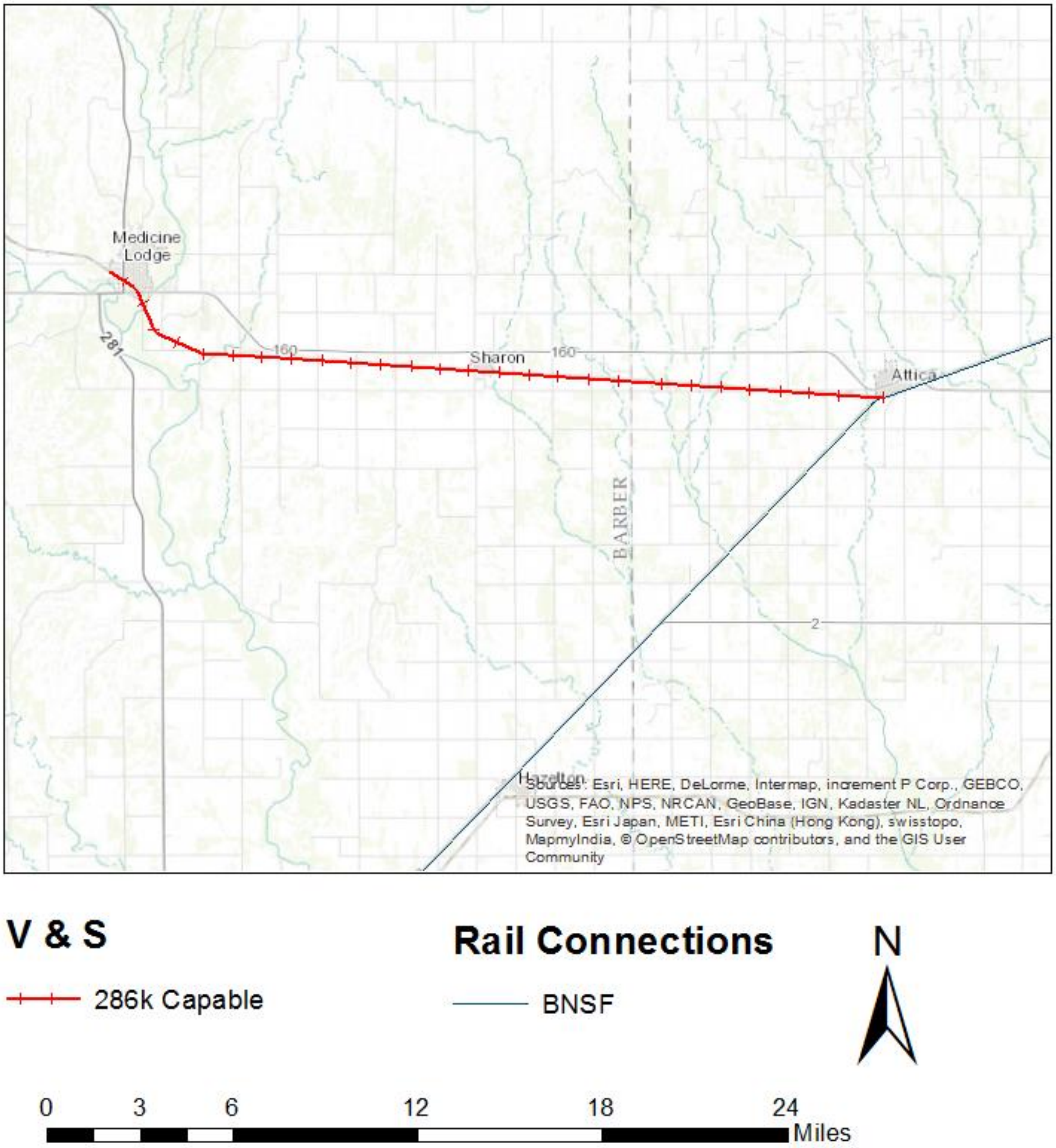
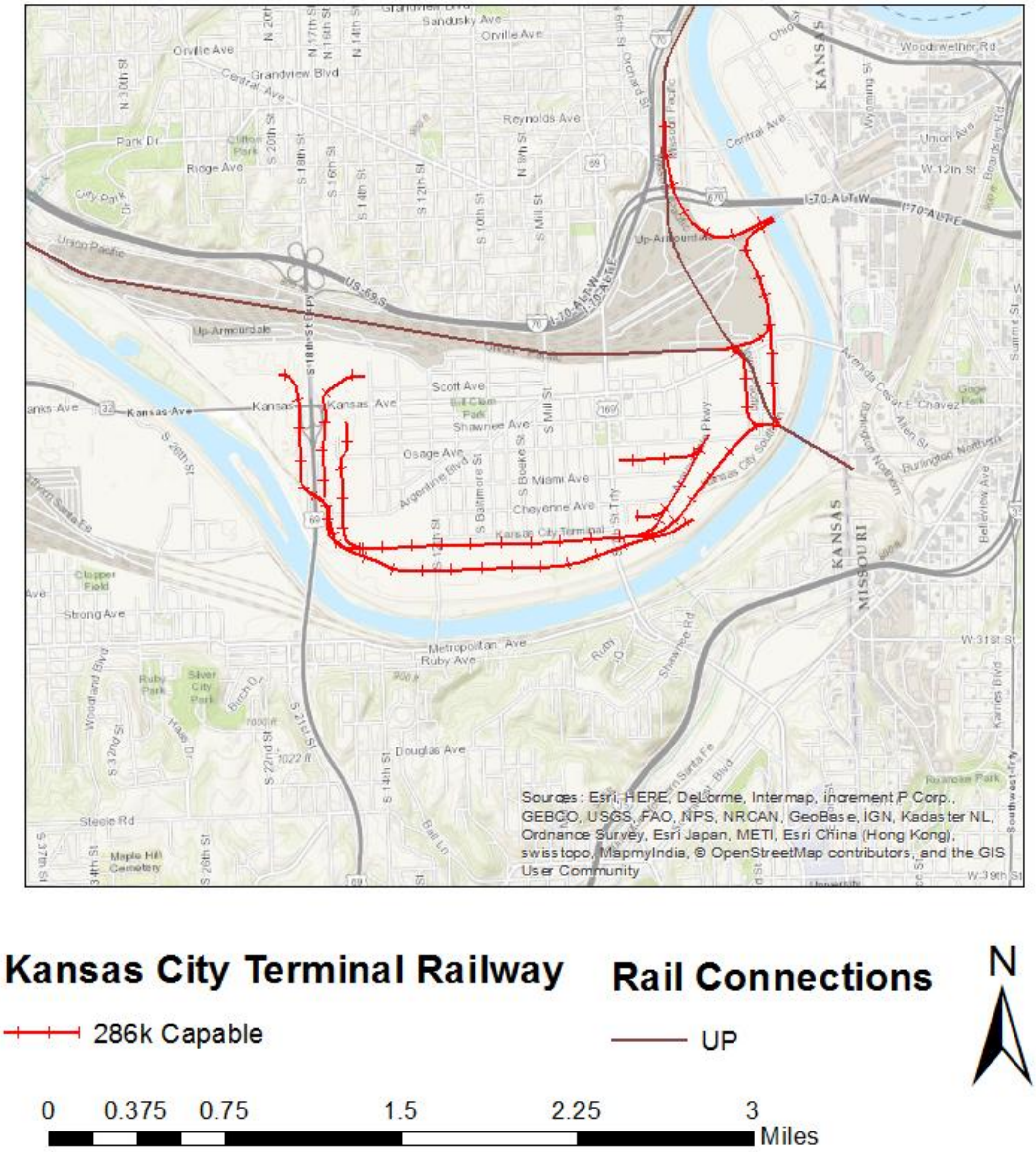


Figure 4.11 Weight Capacity Map for the V&S Railway

4.2.11 Kansas City Terminal Railway Company

The Kansas City Terminal (KCT) railway serves as a joint operation for the major freight railroads serving the Kansas City metropolitan area. The Kaw River Railroad (KAW), a subsidiary of WATCO, provides industry switching and operations for KCT. KCT consists of approximately 85 miles (137 km) of track sections owned by BNSF, with 33 miles (52 km) of track in Kansas and the rest in Missouri. The major commodities handled by KCT include grain products, paper, cement, lumber, and plastics. In 2015 KCT transported more than 16,000 carloads of goods. Figure 4.12 illustrates the weight capacity of the KCT.

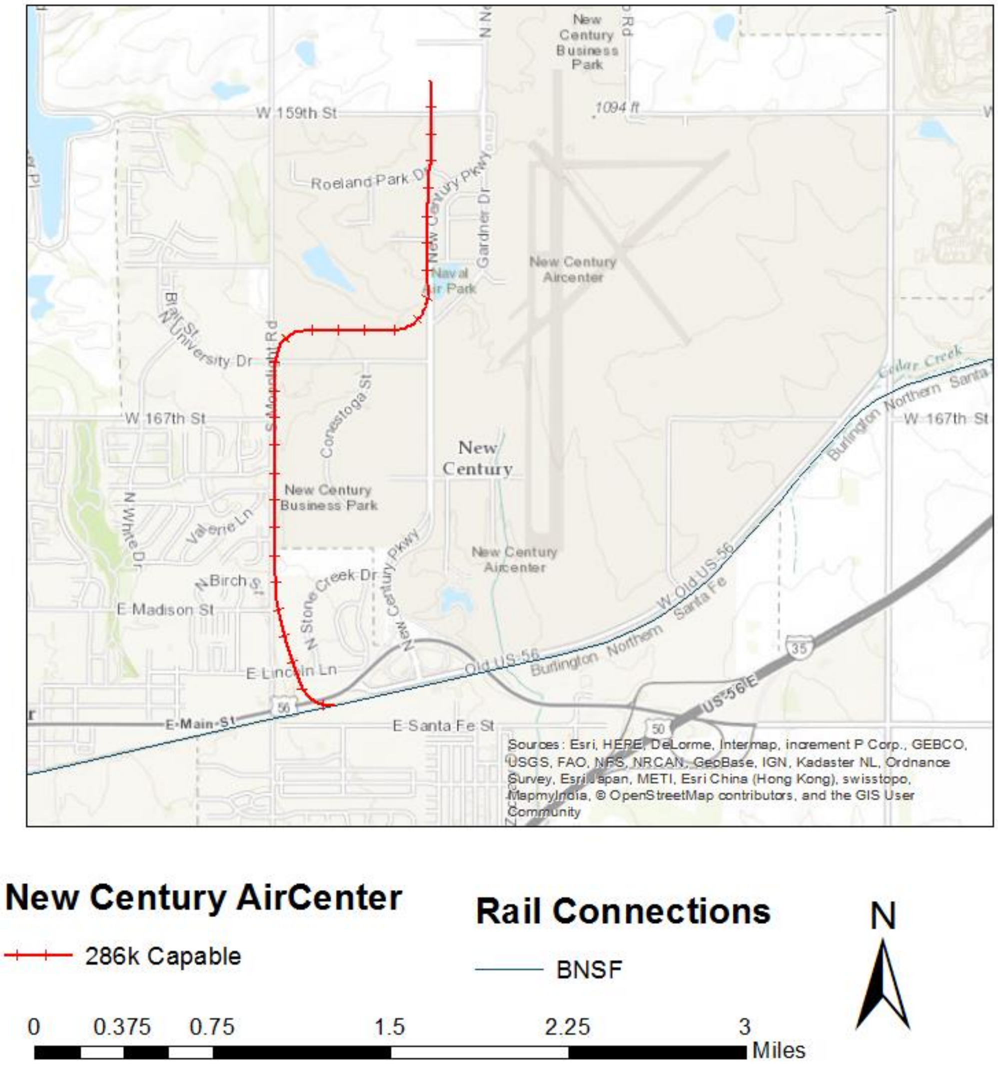


Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.12 Weight Capacity Map for the Kansas City Terminal Railway

4.2.12 New Century AirCenter

The New Century Air Center (NCA) railroad provides rail service to New Century AirCenter/JCAX, a 2,300-acre (9.3 km^2) inland port along the I-35 North American Free Trade Agreement (NAFTA) corridor. NCA is a 5-mile track (8 km) section that provides switching services to meet the air center's demands. The track section includes weigh-in-motion technology for railcar identification and reporting systems. NCA transports a wide variety of goods, including soybean oil, lumber, steel, acetic acid, and plastic beads. In 2015 NCA transported seven hundred 263,000 lb (119,294 kg) and two hundred and fifty 286,000 lb (129,844 kg) railcars. The only growth for NCA is expected from additional businesses moving to the industrial park. Figure 4.13 shows the route and weight capacity of the NCA, all of which can accommodate 286,000 lb (129,844 kg) railcars.



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.13 Weight Capacity Map for the New Century AirCenter Railroad

4.2.13 Wichita Terminal

The Wichita Terminal Association (WTA) is owned by BNSF and UP railroads, and both Class I railroads oversee maintenance and dispatching on the line as well as finance required track maintenance. WTA primarily transports grain products such as wheat, flour, soybeans, and soybean oil, as well as scrap metals. In 2015 WTA transported approximately 3,750 carloads on an entire track structure that is compatible with 286,000 lb (129,844 kg) railcars. WTA is planning to construct an additional storage track for 12 cars in 2017. Figure 4.14 contains a map of the WTA railroad.

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.14 Weight Capacity Map for the Wichita Terminal Association Railroad

4.3 Proposed Project Upgrade Prioritization Tiers

Prioritization of proposed engineering projects, specifically railroads, depends on the project's ability to improve the mobility, safety, economic development, and environmental impacts of its serving region more significantly than competing projects. However, differences of opinion between stakeholders, unforeseen events, local politics, and shifting economic circumstances can complicate the prioritization of large-scale railroad improvement projects. This research study quantified the potential impact of proposed upgrades to Class III track structures using collected shipping data and the capability of corridors to move goods to Class I railroads. Based on survey results and interviews with company officials, a project prioritization is proposed using a three-tiered approach.

As shown in Table 4.10, the projects proposed in the tiered system were selected from railroad representatives' answers to Question 13 of the survey as described in section 3.1. Tier One projects are expected to provide significant improvements to allow two Class III railroads to transport 286,000 lb (129,844kg) railcars. Tier Two and Tier Three projects are expected to provide less benefit than Tier One projects, but they will improve Class III railroad infrastructures to better accommodate 286,000 lb (129,844 kg) railcars. The proposed tiers allow for a degree of flexibility. For example, if an unexpected safety concern occurred on a Tier Two corridor, the project can be upgraded to a Tier One status. However, detailed engineering assessments of the bridges, rail, and track structures are needed to determine the cost for each project, potentially changing project tier arrangements or providing additional subprojects to track sections overlooked in this study.

Table 4.10 Proposed Tiered System

Rail Improvement Project	Rational
Tier One	
KO's Scott City Subdivision	The Scott City subdivision contains one of Kansas's longest sections of track (203 miles [327 km]), which currently moves 286,000 lb (129,844 kg) at 10 mph (16 kmh) for most of the stretch
KYLE's Belleville and Concordia Subdivisions	These projects would allow their Phillipsburg customers to ship and receive 286,000 lb (129,844 kg) railcars
WTA's Additional Storage Track	WTA plans to add a 12-car length storage track in 2017
Tier Two	
One of SKOL's Subdivisions: Moline, Chanute, Coffeyville, or Tulsa	SKOL is currently evaluating these subdivisions to upgrade track capacity based on customer needs with consideration of operational efficiencies
Improvement of KYLE's Goodland Subdivision	This project will allow grain shipments in in Phillipsburg to reach an interchange in 286,000 lb (129,84 kg) loadings
Tier Three	
Repair of VSR's Aging Bridges	The most serious, relevant threat to the VSR is their aging bridges

4.4 GPR Results

For the clean ballast testing, GPR scans were collected directly after adding six gallons (22.7 L) of water to 24 in (0.61 m) of ballast and for time intervals of 12 hours for a week. A selected series of representative scans showing the condition of the ballast dry, directly after wetting, and 12, 144, and 168 hours after the addition of the water is shown in Figure 4.15. The two-way travel time is the time elapsed since the initial pulse of electromagnetic energy. The GPR amplitude is a measure of the received reflection of the wave at each point in time. Using the two-way travel time at the bottom of the box read from the GPR scans, the dielectric constant was calculated using Equation 2.4 The propagation of the survey wave through the material in Figure 4.15 is signified as the distance between the two major peaks for each scan, which occur around

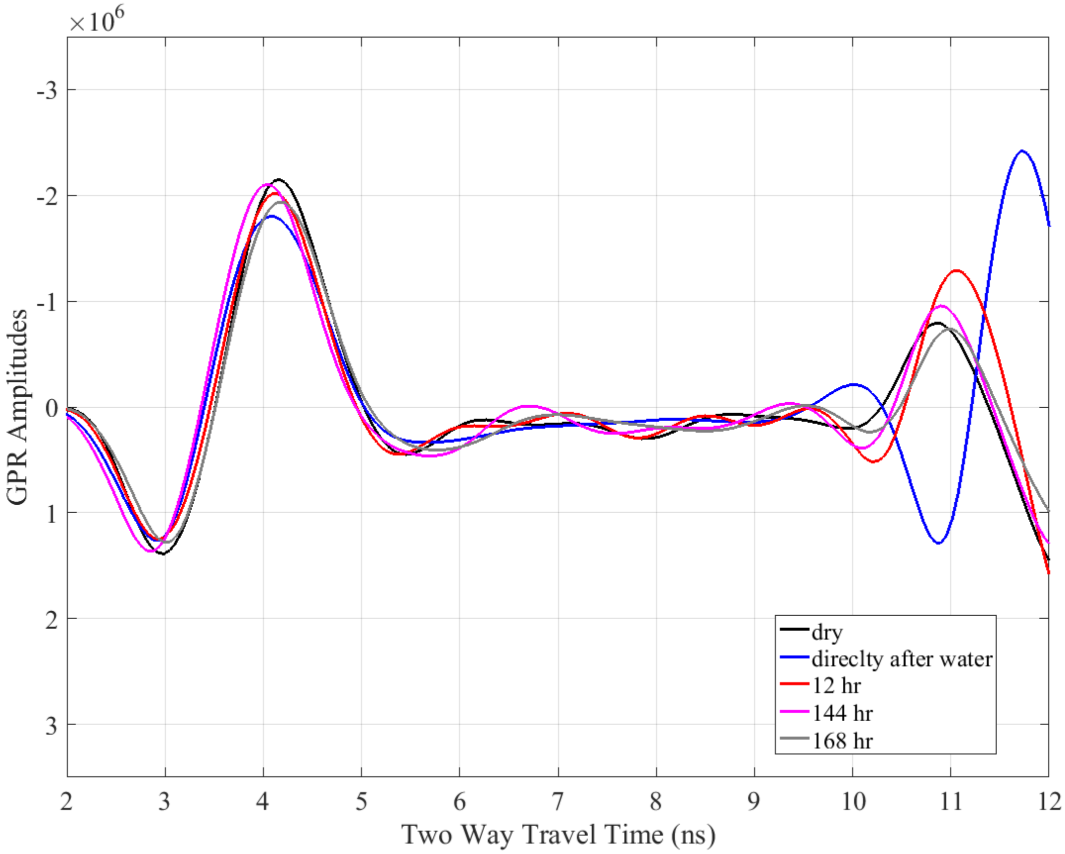


Figure 4.15 Time Lapse of GPR Surveys for Clean Ballast after Initial Wetting

4 and 11 ns two-way travel times. The range of calculated dielectric constant was 3.0-3.6 representing the dry and initially wetted conditions, which are consistent with the values summarized from Clark (2001) and Sussman et al. (2002) in Table 2.5.

For the sand testing, ten gallons (37.9 L) of water was added one gallon (3.8 L) at a time to the smaller test box to collect GPR data for an absorptive geologic material with differing water contents. Figures 4.16 and 4.17 depict the acquired GPR scans for two, four, six, eight and ten gallons (7.6, 15.1, 22.7, 30.2, and 37.9 L) with the corresponding volumetric water contents of 11.6%, 12.3%, 12.71%, 13.1%, and 22.4%, as well as the dry condition. Even though equal amounts of water were added for each data point, the water content of the samples does not increase at a constant rate. This is due to the natural drainage of sand due to a relatively high suction for water contents less than 30 percent, which lead to the water seeping to the bottom of the box after

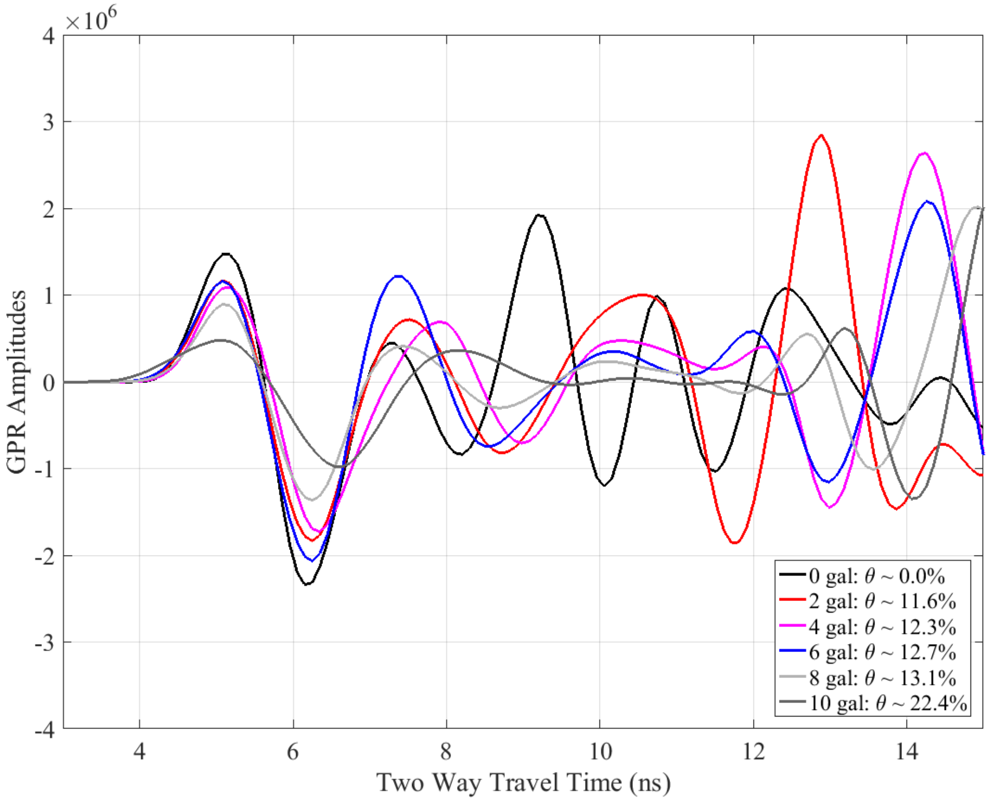


Figure 4.16 Aggregated GPR Surveys for Sand with Varying Water Contents

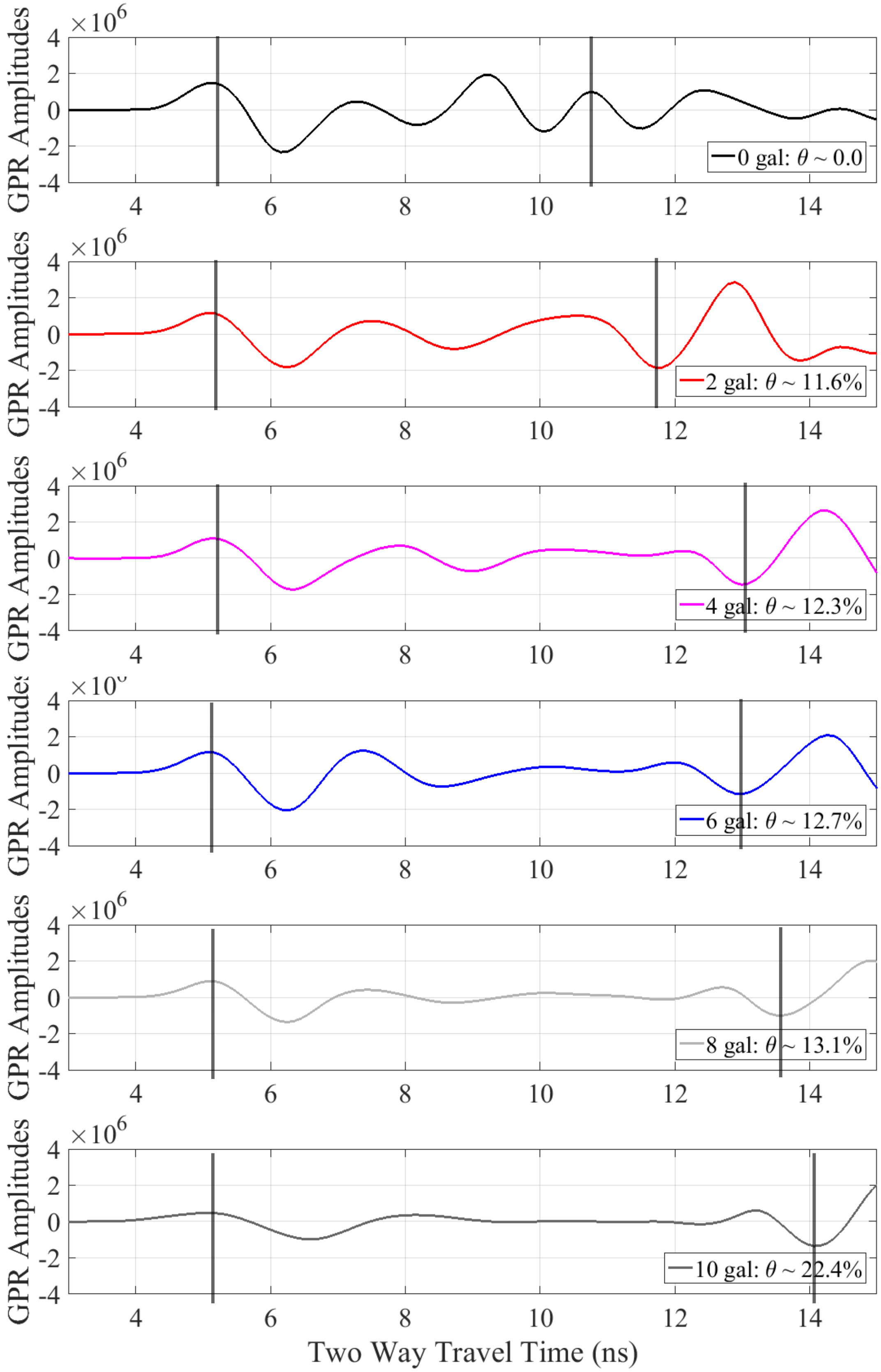


Figure 4.17 Individual GPR Scans for Sand with Varying Water Contents Showing Box Depth

each mixing process, while the soil sample used to determine water content was collected at the top of the box. As the water content of the sample increased, the waves took longer to propagate through the samples. This trend is indicated by the increased distance between the black lines in Figure 4.17. This is the same trend projected by Topp's equation (Equation 2.8); increasing the volumetric water content corresponds to an increase in dielectric content. The values labeled as "calculated" and "measured" were determined using Equation 2.8 and Equation 2.4, respectively. These values are compared in Figure 4.18. For both the measured and calculated values, larger water contents correspond to larger dielectric constants. The percent error comparing the calculated and measured dielectric was calculated by

$$\%_{error} = \left| \frac{(\varepsilon_{r_{calculated}} - \varepsilon_{r_{measured}})}{\varepsilon_{r_{measured}}} * 100 \right| \tag{4.1}$$

where $\varepsilon_{r_{measured}}$ is the measured dielectric constant using the two-way travel time of the GPR scan and the known depth of the test material and $\varepsilon_{r_{calculated}}$ is the calculated dielectric constant

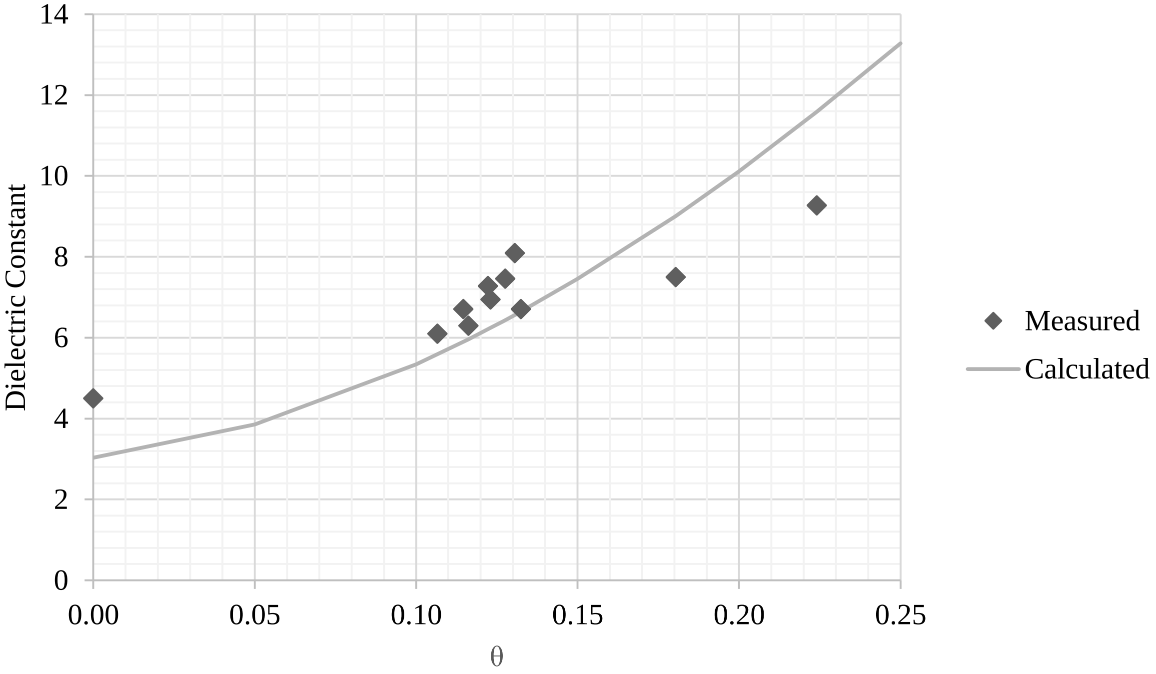


Figure 4.18 Calculated vs. Measured Dielectric Constant by Volumetric Water Content

volumetric water content are shown in Table 4.11. Percent error ranges from 32.73-1.05 percent using Topp's correlation. The results for both the measured and calculated dielectric constants as well as the percent error for each with an average of 14.75. Figure 4.19 shows a direct comparison of the measured and calculated. For all but the two largest values, the measured dielectric constant is larger than the calculated value for the same volumetric water constant.

Table 4.11 Summary of Measured and Calculated Dielectric Constants and Percent Error

θ	Measured	Calculated	Percent Error
0.00	4.50	3.03	32.73
0.11	6.10	5.59	8.37
0.11	6.71	5.90	12.14
0.12	6.30	5.96	5.38
0.12	7.28	6.21	14.69
0.12	6.94	6.24	10.10
0.13	7.46	6.43	13.76
0.13	8.10	6.56	18.98
0.13	6.71	6.64	1.05
0.18	10.10	9.01	10.83
0.22	9.27	11.58	24.93

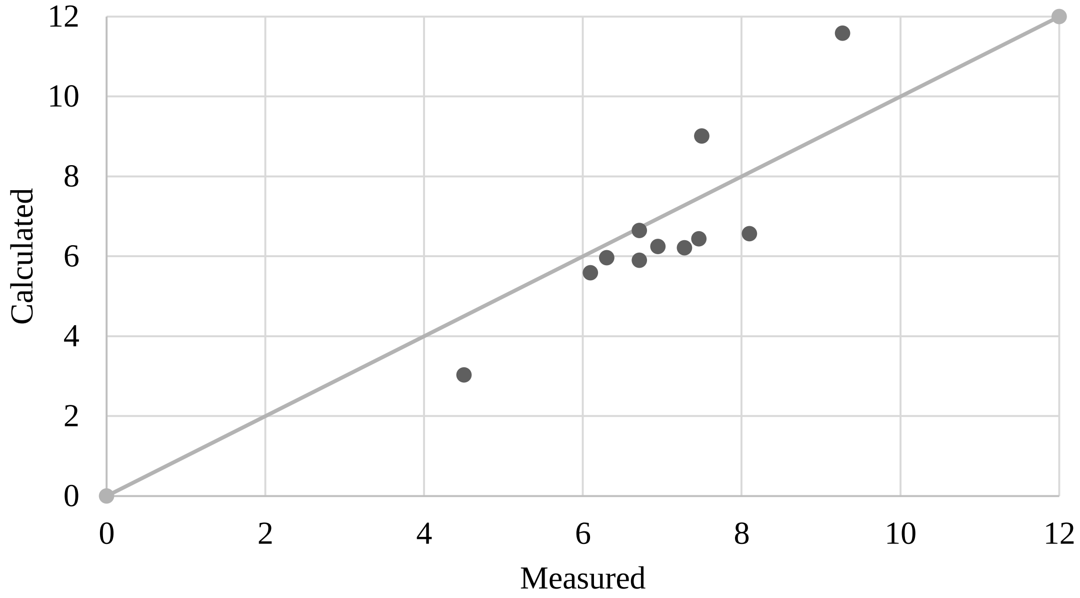


Figure 4.19 Calculated vs. Measured Dielectric Constant Direct Comparison

Chapter 5 - Discussion and Recommendations

5.1 Class III Railroads

Class III railroads are critical for the transportation of goods and services within the United States. Although Class III railroads often transport fewer carloads at slower speeds than Class I railroads due to decades of deferred maintenance of Class III track structure, Class III railroads serve as last and first line operations for customers of manufactured and agricultural goods, providing vital links to the nation's rail network.

The state of Kansas has allocated up to $5 million per year for rail rehabilitation and expansion projects of Class III railroads through the SRSIF program administered by KDOT. The state of Kansas has 14 registered Class III railroads that consist of 1,600 track miles (2,875 km), including switching and terminal yards. With the help of KDOT, researchers at Kansas State University conducted this study to increase understanding of track structure inventory, shipping and carload data, and Class III business climate in 2015. This critical data will allow KDOT to prioritize projects, assist Class III railroads by investing in infrastructure, and maximize the benefit from SRSIF funding.

The research team and KDOT project monitors constructed a survey detailing required operational and structural information. The survey was sent to representatives of the 10 Class III railroad companies currently operating in Kansas; completed surveys were inventoried, organized, and synthesized. Special emphasis was given to understanding the current operational status of each Class III railroad with respect to accommodating railcars weighing 286,000 lb (129,844 kg). During 2015 Class III railroads in Kansas carried approximately 163,300 carloads, approximately equivalent to the fully loaded capacity of 600,000 semi-trucks.

Although approximately 64 percent of Class III rail weigh more than 100 lb/yd (47 kg/m), only 30 percent, or 560 miles, of track in Kansas can currently accommodate an HAL railcar. The survey also determined that many Class III railroads in Kansas contain portions of track structure that are rated for faster operating speeds (up to 25 mph [40 kmh]) but still require locomotives to travel at 10 mph (16 kmh) to minimize the risk of derailment.

Based on the survey data, Class III representative recommendations, and comparisons of Class III railroad data between companies, the research team developed a proposed list of priority upgrade projects for KDOT to consider. The list was divided into three tiers based on priority rankings: Tier One projects are given the highest priority for funding, while Tier Three projects are given the least priority based on total expected system benefits for each project as determined by shipping characteristics and connections to Class I railroads. The research team recommended KO's Scott City subdivision and KYLE’s Belleville and Concordia subdivisions as Tier One projects. WTA’s additional storage track was also recommended, but this storage track is currently fully funded by the BNSF railway.

5.2 GPR

This research is the first step towards determining whether GPR can accurately determine the percent fines and water content in railroad ballast by creating soil characteristic curves following the methodology Sahin (2014) developed for base course material (2014). This study has established that the testing procedures defined in the methodology section are able to determine the dielectric constant of geologic materials in the laboratory and that water increases the observed dielectric constant. Since water tends to be the controlling factor of most GPR surveys, being able to correlate differing FI to suction would be helpful to determine the degree of fouling in the field using a combination of GPR surveys and calculated volumetric water content since accurate GPR surveys are currently limited when volumetric water content is variable. Laboratory tests were performed on clean ballast provided by BNSF and sand.

The effect of decreasing volumetric water content on clean ballast over time was recorded by wetting the ballast in a large test box and collecting scans hourly for the first 6 hours, then at the 12, 18, and 24 hour marks and at the multiples of 12 hours for a week. It was determined that the clean ballast is slightly affected by the increased water content, in that the dielectric constant increased from 3.0 to 3.6. However the ballast drained most of the applied water quickly, so obtaining data with differing water contents was difficult.

Sand was then selected as an available geo-maerial with higher water retention than clean ballast. A test box was then filled with the sand and water was thoroughly mixed in one gallon (3.8 L) at a time for ten gallons (37.8 L). GPR scans and samples for determining the water content were collected between each additional gallon. The correlaton between water content and the GPR surveys confirmed that an increase in water content corresponsed with an increase in the dilectric constant. The observed dielectric constant increased from 4.5 to 11.6 by increasing the volumetric water content from 0.0 to 22.4 percent

5.2.1 Future Work

To continue this research, fouled ballast will be obtained. Then the laboratory sand testing procedure will be repeated with the fouled ballast varying both fouling indexes and water contents. This will document the interaction between the volumetric water content and the change in void ratio coinciding with differing fouling indexes. A correlation of the observed differences in the dielectric constant obtained by the GPR surveys, soil characteristic curves will be created.

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Appendix A - Returned Surveys

BLUE RAPIDS:

1. What are the top five commodities shipped on your railroad?

Commodities:	**Industrial Gypsum Plasters**	**-**	**-**	**-**	**-**

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.

    No

3. What are your main locations for originating and terminating traffic?

    Originating: Blue Rapids
    Terminating: Various, North America

4. Is your railroad owned by a parent company? If so, which one?

    Georgia-Pacific Gypsum LLC

5. What are your railroad's primary corridors? Feeder line corridors?

    Primary: Georgia-Pacific Gypsum, Blue Rapids KS to UPRR, Marysville KS
    Feeder: N/A

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
    a) Subdivisions and key segment route miles
    b) Gross ton-miles per year
    c) Number of slow orders
    d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season
    e) Total revenue
    f) Percentage non-class I line revenue

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
    a) FRA Track Class and operating speed
    b) Current operating speed
    c) Jointed or welded rail
    d) Rail weight
    e) Rail age
    f) Ballast conditions (type of ballast, depth, etc.)
    g) Tie age and condition (i.e., plate cut, split, etc.)
    h) Weight capacity

i) Structure sufficiency data (capability of handling 286,000 pound cars)

Subdivision	***Length (miles)***	***Number of Slow Orders***	***Average 263,000 lb Railcars Per***				***Average 286,000 lb Railcars Per***			
			Week	***Month***	***Year***	***Season***	***Week***	***Month***	***Year***	***Season***
Column 1	9.5	1 for entire	10	-	-	-	0	-	-	-

Subdivision	***FRA Track Class***	***Current Operating Speed***	***Jointed or Welded Rail***	***Rail Weight***	***Rail Age***	***Ballast Condition***				***Tie Age***	***Tie Cond.***	***Weight Capacity***
						Type	***Depth***	***Age***	***Other***			
Column 1	Exempt	10	Jointed	90	100	Chat	12”	100	-	1 to 100	fair	268K

8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

   We do not have rights on another railroad.
   We have a contract in place to extend rights to the Union Pacific for twice weekly switching.

9. Does you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?

   No.

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

    Undetermined at this time.

11. Does your company make projections as to future growth in your business?

    No projected growth reported

    a) If so, are these by tonnage or number of carloads?
       NA (see 11)

    b) If so, what is the basis for these projections?
       NA (see 11)

    c) What are your most recent projections for the next three years?

Year	**2015**	**2016**	**2017**
Projection	**NA**	**NA**	**NA**

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

    NA

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

    No

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

    No

CIMARRON VALLEY

1. What are the top five commodities shipped on your railroad?

Commodities:	**Wheat**	**Milo**	**Fuel oil**	**Soybean meal**	**Corn**

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.
   Our main commodities are grain, dependent on harvests and markets

3. What are your main locations for originating and terminating traffic?
   Originating: Dodge City, KS
   Terminating: Dodge City, KS

4. Is your railroad owned by a parent company? If so, which one?
   The Western Group, Ogden, UT

5. What are your railroad's primary corridors? Feeder line corridors?
   Primary: Southwest Kansas, Southeastern Colorado, Oklahoma Panhandle
   Feeder: BNSF

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
   a) Subdivisions and key segment route miles CV Sub – 151.04 miles, Manter Sub – 103.43 miles
   b) Gross ton-miles per year 42,954 miles traveled 2015
   c) Number of slow orders No slow orders – Everything is 10 mph
   d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season 60% - 40%
   e) Total revenue N/A
   f) Percentage non-class I line revenue 7%

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
   a) FRA Track Class and operating speed
   b) Current operating speed
   c) Jointed or welded rail
   d) Rail weight
   e) Rail age
   f) Ballast conditions (type of ballast, depth, etc.)
   g) Tie age and condition (i.e., plate cut, split, etc.)
   h) Weight capacity
   i) Structure sufficiency data (capability of handling 286,000 pound cars)

Subdivision	**Length (miles)**	**Number of Slow Orders**	**Average 263,000 lb Railcars Per**				**Average 286,000 lb Railcars Per**			
			Week	**Month**	**Year**	**Season**	**Week**	**Month**	**Year**	**Season**
CVR	255	NA	253.84	549.99	6600	-	169.22	366.66	4400	-

Subdivision	**FRA Track Class**	**Current Operating Speed**	**Jointed or Welded Rail**	**Rail Weight**	**Rail Age**	**Ballast Condition**				**Tie Age**	**Tie Cond.**	**Weight Capacity**
						Type	**Depth**	**Age**	**Other**			
CVR	1	10 mph	Jointed	85-136	20-97	Green Granite	12-15” AVG	5-25	-	0-75	Fair	263000-286000

8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

   No

9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?

   Yes, State already has it

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

    No

11. Does your company make projections as to future growth in your business?

    Yes

    a) If so, are these by tonnage or number of carloads?

       Number of carloads

    b) If so, what is the basis for these projections?

       Grain harvests and markets

    c) What are your most recent projections for the next three years?

Year	**2015**	**2016**	**2017**
Projection	**10%**	**10%**	**10%**

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

    Yes

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

    Not at this time

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

    CV Sub is already doing 286,000 cars. Manter Sub can't handle 286000 cars. Half of our business is on the Manter Sub.

GARDEN CITY WESTERN RAILROAD:

1. What are the top five commodities shipped on your railroad?

Commodities:	**Molasses**	**Scrap**	**Fertilizers**	**Meal**	**Utility poles**

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.

   Not really seasonal, but by market changes. (ex. Scrap market is very weak, as a result scrap shipments are down considerably in 2015 from that in 2014)

3. What are your main locations for originating and terminating traffic?

   Originating: Texas
   Terminating: Texas

4. Is your railroad owned by a parent company? If so, which one?

   Yes – Pioneer Railcorp

5. What are your railroad's primary corridors? Feeder line corridors?

   Primary: first 4 miles of West Line which runs from Garden City to Wolf
   Feeder: North Line – runs from Garden City to Shallow Water

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
   a) Subdivisions and key segment route miles
   b) Gross ton-miles per year
   c) Number of slow orders
   d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season
   e) Total revenue
   f) Percentage non-class I line revenue

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
   a) FRA Track Class and operating speed
   b) Current operating speed
   c) Jointed or welded rail
   d) Rail weight
   e) Rail age
   f) Ballast conditions (type of ballast, depth, etc.)
   g) Tie age and condition (i.e., plate cut, split, etc.)
   h) Weight capacity
   i) Structure sufficiency data (capability of handling 286,000 pound cars)

Subdivision	***Length (miles)***	***Number of Slow Orders***	***Average 263,000 lb Railcars Per***				***Average 286,000 lb Railcars Per***			
			Week	***Month***	***Year***	***Season***	***Week***	***Month***	***Year***	***Season***
West Line	14	None	26	112	1344	336	-	-	-	-
North Line	28	None	1	4.5	50	12	-	-	-	-

Subdivision	***FRA Track Class***	***Current Operating Speed***	***Jointed or Welded Rail***	***Rail Weight***	***Rail Age***	***Ballast Condition***				***Tie Age***	***Tie Cond.***	***Weight Capacity***
						Type	***Depth***	***Age***	***Other***			
Main	1	10MPH	Jointed	70/80/90	63+	-	+/-8”	-	-	Old	-	-
West Main 0-3.0	1	10MPH	Jointed	70	63+	-	-	-	-	Some New	Good	286K

8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

    No

9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights? Nothing but our marketing Maps, or create on in Google Earth

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

    No

11. Does your company make projections as to future growth in your business?

    Yes

    a) If so, are these by tonnage or number of carloads?

       Carloads

    b) If so, what is the basis for these projections?

       Data received from current/projected customers

    c) What are your most recent projections for the next three years?

Year	**2015**	**2016**	**2017**
Projection	**1200**	**1375**	**1450**

Note: GCW had one of our customers consolidate its operations and therein closing its doors on the facility in Garden City on the GCW

-

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

    Yes

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

    Yes. Data provided above regarding carload shipments is based on 2014 traffic. At this time, GCW has completed MP 0-3.0, for 286K and Upgrade of Yard Switches, from I/C to West Line MP 3.0, 286K. Again – GCW on this portion is now 286 capable – which at this time covers 95% of all inbound/outbound traffic.

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

    No.

KANSAS AND OKLAHOMA:

1. What are the top five commodities shipped on your railroad?

Commodities:	**Wheat/Sorghum Grains**	**Flammable Gases/NGL's**	**Class 8 Corrosive Material**	**Fertilizer**	**Soybean Meal**

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.

   The summer and winter harvest for grain is affected by Mother Nature which dictates the beginning of harvest and how many railcars that we will move.

3. What are your main locations for originating and terminating traffic?

   Originating: Various locations
   Terminating: Wichita, Hutchinson, Newton, McPherson, Salina, Abilene

4. Is your railroad owned by a parent company? If so, which one?

   WATCO Companies

5. What are your railroad's primary corridors? Feeder line corridors?

   Primary: Conway Springs, Great Bend, Hoisington, Hutchinson, Kingman, McPherson, Newton, Salina and Scott City

   Feeder: Hutchinson, Wichita, McPherson, Newton, Salina

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
   a) Subdivisions and key segment route miles
   b) Gross ton-miles per year
   c) Number of slow orders – P = Permanent and Temporary Slow Orders Vary from week to week
   d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season
   e) Total revenue
   f) Percentage non-class I line revenue

Subdivision	***Length (miles)***	***Number of Slow Orders***	***Average 263,000 lb Railcars Per***				***Average 286,000 lb Railcars Per***			
			Week	***Month***	***Year***	***Season***	***Week***	***Month***	***Year***	***Season***
Conway Springs	101.3	5 P	42	185	2220	-	243	1050	12600	-
Kingman	60.2	0 P	10	41	492	-	-	0	-	-
Hutchinson	52.9	3 P	-		-	-	46	201	2412	-
Great Bend	120.1	1 P	-	-	-	-	89	384	4608	-
Hoisington	104.9	2 P	32	141	1692	-	-	-	-	-
Scott City	203.4	1 P	96	415	4980	-	-	-	-	-
McPherson	13.2	2 P	-	-	-	-	139	601	7212	-
Newton	27	1 P	-	-	-	-	12	51	612	-
Salina	82.7	0 P	23	101	1212		100	430	5160	

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
    a) FRA Track Class and operating speed
    b) Current operating speed
    c) Jointed or welded rail
    d) Rail weight
    e) Rail age
    f) Ballast conditions (type of ballast, depth, etc.)
    g) Tie age and condition (i.e., plate cut, split, etc.)
    h) Weight capacity
    i) Structure sufficiency data (capability of handling 286,000 pound cars)

Subdivision	FRA Track Class	Current Operating Speed	Jointed or Welded Rail	Rail Weight	Rail Age	Ballast Condition				Tie Age	Tie Cond.	Weight Capacity
						Type	Depth	Age	Other			
Conway Springs	2/1	25/20/10 mph	Jointed	85/90/112	1860-1944	Limestone	6”	Varies	-	Varies	Varies	263
Kingman	1	10 mph	Jointed	75/85/90	1904-1912	Limestone	6”	Varies	-	Varies	Varies	263
Hutchinson	1	10/25 mph	Both	110/115	1934-1947	Granite/ limestone	6/8”	Varies	-	Varies	Varies	286
Great Bend	EX/2	25/10 mph	Jointed	90/110	1909-1925	Limestone	6”	Varies	-	Varies	Varies	263/286
Hoisington	1/2	25/10 mph	Both	90/132	1952	Granite	8”	Varies	-	Varies	Varies	286
Scott City	1/2/EX	10/25 mph	Both	85/90/115	1904-1908	Limestone	6”	Varies	-	Varies	Varies	263
McPherson	1	10	Both	75/85/115	1902-1945	Limestone	6”	Varies	-	Varies	Varies	263/286
Newton	2	25	Welded	112	1943-1951	Granite	8”	Varies	-	Varies	Varies	286
Salina	1	10	Both	70/90/115	1913-1945	Limestone	6”	Varies		Varies	Varies	263

8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

The K&O has trackage rights on the Union Pacific to run from Salina to Abilene for interchange with the BNSF

9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?

Find attached with one correction… Wichita to Frontier should be in red (286,000 lbs)

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

No

11. Does your company make projections as to future growth in your business?

We forecast/project for the next year in September/October

d) If so, are these by tonnage or number of carloads?

Carloads

e) If so, what is the basis for these projections?

Projections are based on input from our top customers, historical data, 3 & 5 year rolling averages for grain/agriculture and a few are based on a percentage increase

f) What are your most recent projections for the next three years?

Year	2015	2016	2017
Projection	42,222	43,222	44,222

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

Yes

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

Currently creating a plan to make upgrades on the Scott City Sub but no set time table.

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

We just try to improve every day.

KYLE

1. What are the top five commodities shipped on your railroad?

Commodities:	**winter wheat**	**sorghum**	**roofing granules**	**corn**	**-**

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.

   With wheat, sorghum and corn, there is a definite seasonality of shipments. Peak season for transportation is typically July / August / September

3. What are your main locations for originating and terminating traffic?

   Originating: Downs, Glen Elder, Goodland
   Terminating: Phillipsburg, Goodland

4. Is your railroad owned by a parent company? If so, which one?

   KYLE is a wholly-owned subsidiary of Genesee & Wyoming Inc.

5. What are your railroad's primary corridors? Feeder line corridors?

   Primary: Wheat: KYLE – St. Louis or Kansas City – points east and south Sorghum: KYLE – Gulf Coast ports
   Corn: KYLE – mixed, predominately southern states
   Roofing Granules: Wisconsin – KYLE

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
   a) Subdivisions and key segment route miles
   b) Gross ton-miles per year: Not readily available, you can estimate using train frequency, estimated number of railcars per train, and length of subdivisions.
   c) Number of slow orders
   d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season

      Total revenue: Confidential. As a publicly traded company that reports unified financial results, G&W cannot make a non-public disclosure of financially material information. Providing a revenue or car load projection for KYLE would fall into this prohibition.
   e) Percentage non-class I line revenue: Amount of KYLE Local Traffic is approx. 2 percent.

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
    a) FRA Track Class and operating speed
    b) Current operating speed
    c) Jointed or welded rail
    d) Rail weight
    e) Rail age
    f) Ballast conditions (type of ballast, depth, etc.)
    g) Tie age and condition (i.e., plate cut, split, etc.)
    h) Weight capacity
    i) Structure sufficiency data (capability of handling 286,000 pound cars)

Subdivision	***Length (miles)***	***Number of Slow Orders (Appox. Number of miles of slow orders)***	***Average 268,000 lb Railcars per***				***Average 286,000 lb Railcars Per***			
			Week	***Month***	***Year***	***Season***	***Week***	***Month***	***Year***	***Season***
Solomon Sub	57	0 (0 Miles)	-	-	-	-	6-8 trains/week	-	-	-
Concordia Sub	53	1 (21 Miles)	6 trains / week	-	-	-	-	-	-	-
Yuma	15	Predominately OSS due to Republic River Bridge OSS	currently nominal	-	-	-	-	-	-	-
Bellville	96	9 (40 miles)	6 trains / week	-	-	-	-	-	-	-
Phillipsburg	140	12 (58 miles)	6 trains / week	-	-	-	-	-	-	-
Goodland	97	8 (45 miles)	6 trains / week	-	-	-	-	-	-	-

Subdivision	***FRA Track Class****	***Current Operating Speed***	***Jointed or Welded Rail***	***Rail Weight***	***Rail Age***	***Ballast Condition***				***Tie Age***	***Tie Cond.***	***Weight Capacity***
						Type	***Depth***	***Age***	***Other***			
Solomon Sub	1	10 mph	Predominately jointed	mix, 90 to 115 lb	approx 70 years and newer	rock	-	-	upgrade desirable	-	fair	286k
Concordia Sub	2	largely 10 mph due to slow orders, some 25 mph	Predominately jointed	mix, 90 to 115 lb	approx 70 years and newer	rock	-	-	upgrade desirable	-	fair	268k
Yuma Sub	1	10 mph (what is currently in-service)	Predominately jointed	mix, 90 to 115 lb	approx 70 years and newer	rock	-	-	upgrade desirable	-	fair	268k
Bellville Sub	2	largely 10 mph due to slow orders, some 25 mph	Predominately jointed, with sections of CWR	mix, 90 to 115 lb	approx 70 years and newer	rock	-	-	fair	-	fair	268k
Phillipsburg	3	largely 10 mph due to slow orders, some 30 mph	Predominately jointed, with sections of CWR	mix, 90 to 115 lb	approx 70 years and newer	rock	-	-	fair	-	fair	268k
Goodland	3	largely 10 mph due to slow orders, some 30 mph	Predominately jointed, with sections of CWR	mix, 90 to 115 lb	approx 70 years and newer	rock	-	-	upgrade desirable	-	fair	268k

NOTE: Timetable speed used for Class of Track definition, however, actually operating speeds substantially less due to slow orders on the subdivisions. If slow orders are in close proximity, timetable allowed track speed is not obtained between the slow orders

8 Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

KYLE trackage rights over other railroads:

Temporary BNSF trackage rights: Concordia to
Courtland Permanent Union Pacific trackage rights:
Salina to Solomon

No current trackage rights for another railroad over KYLE

9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?

Such a map is not readily available. The ONLY section of KYLE rated to handle 286,000 lb freight cars is Downs to Solomon. The rest of the railroad has a freight car weight limit of 268,000 lbs. It is very important to note, however, that handling 286,000 lb freight cars over subdivisions not now rate to handle such shipments will require investments in bridges, rail and track structure (ties and ballast). Such investments vary by subdivisions. A more current detailed assessment would be necessary to provide a complete understanding of the limitations on each subdivision.

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

Like with any other freight railroad, future viability is dependent upon handling enough traffic to create a positive cash flow to ensure adequate maintain and coverage of expenses. Clearly the failed bridge over the Republic River on the Yuma Sub, resulting in the bulk of this subdivision being placed into Out of Service (OOS) status, has put a significant question on the future of this subdivision.

11. Does your company make projections as to future growth in your business?

As a publicly traded company that reports unified financial results, G&W cannot make a non-public disclosure of financially material information. Providing a revenue or car load projection for KYLE would fall into this prohibition. Having stated this, it is possible for others to estimate future KYLE traffic by considering two markets: Kansas grain, specifically wheat, and roofing materials. These two markets directly drive KYLE carloads in its two largest traffic bases. Both markets are largely impacted by weather patterns and trends; for grain in determining the quality and quantity of the wheat harvest, and for roofing materials by the frequency of severe weather that would create heavy demand for such materials. Secondary factors impacting future KYLE traffic would be the overall strength of the U.S. dollar affecting the competitiveness of Kansas grains in the world marketplace and the U.S. housing market affecting the demand for roofing materials.

a) If so, are these by tonnage or number of carloads?

Not available

b) If so, what is the basis for these projections?

Projections not available

c) What are your most recent projections for the next three years?

Year	**2015**	**2016**	**2017**
Projection	**-**	**-**	**-**

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

    Locomotive fleet on KYLE is not limiting factor for the railroad to handle 286,000 lb freight cars over a large amount of its route structure. Bridge, rail and overall track structure are the limiting factors.

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

    There are no immediate plans to increase the 268,000 lb weight limited subdivisions of the KYLE to 286,000 lbs. If financially possible, it would be desirable to increase the Bellville and Concordia subdivisions to allow customers on the Phillipsburg subdivision to ship and receive 286,000 lb rail loadings, and to improve the Goodland Subdivision to allow for grain shipments in the Phillipsburg area to reach interchange in 286,000 lb car loadings.

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

    No, increasing the ability of KYLE to handle 286,000 lb freight cars is certainly a desirable long term objective for the railroad. Customers will be able to reach their customers or raw materials more economically, and be better able to compete in their marketplaces. Based on the mileages involved, with the associated amount of bridge, rail and roadbed upgrades that would be necessary to increase the railroad to a universal 286,000 lb railcar weight limit, this is a long term focus and will require public – private partnerships to realize. A detailed assessment of bridges, rail and track structure would be required for each KYLE subdivision (except for the Solomon Subdivision) to determine the cost to reach a 286,000 lb load limit. It is clearly beyond the current financial ability of KYLE to make all of these investments in the immediate future.

SOUTH KANSAS AND OKLAHOMA

1. What are the top five commodities shipped on your railroad?

Commodities:	**Cement**	**Chemicals**	**Sand**	**Rock**	**Grain and Grain Products**

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.

   South Kansas & Oklahoma Railroad (SKOL) moves three of its five top commodities, during construction season which includes cement, sand and rock. Grain and grain products also run with seasonality due to harvest. SKOL serves a diverse customer base allowing us to move shipments of chemicals, coal, steel and plastics year round; in addition we serve three dimensional shippers.

3. What are your main locations for originating and terminating traffic?

   Originating: Coffeyville, KS; Chanute, KS; Humboldt, KS; Moline, KS
   Terminating: Coffeyville, KS; Pittsburg, KS; Wichita, KS; Tulsa, OK

4. Is your railroad owned by a parent company? If so, which one?

   Watco Companies is the parent company of SKOL.

5. What are your railroad's primary corridors? Feeder line corridors?

   Primary: Chanute Subdivision, Coffeyville Subdivision, Moline Subdivision, Neodesha Subdivision, Gorilla Subdivision, Tulsa Subdivision
   Feeder:Union Pacific Railroad – Interchange points at Coffeyville, KS; Winfield, KS; Tulsa, OK. BNSF Railway – Interchange points at Columbus, KS, Tulsa, OK; Winfield, KS. Kansas City Southern – Interchange point at Pittsburg, KS. Kansas & Oklahoma Railroad – Interchange point at Wichita, KS. Stillwater Central Railroad – Interchange point at Tulsa, OK. Sand Springs Railroad – Interchange point at Tulsa, OK.

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
   a) Subdivisions and key segment route miles
   b) Gross ton-miles per year
   c) Number of slow orders
   d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season
   e) Total revenue

   $32 million

   f) Percentage non-class I line revenue

   53% which includes freight revenue only

Subdivision	Length (miles)	Number of Slow Orders	Average 263,000 lb Railcars Per				Average 286,000 lb Railcars Per			
			Week	Month	Year	Season	Week	Month	Year	Season
Chanute	39.2	12	210	838	10,058	-	94	377	4525	-
Coffeyville	17	7	574	2295	27,541	-	112	448	5374	-
Tulsa	100	20	342	1368	16,412	-	-	4	48	-
Neodesha	70	7	488	1954	23,455	-	26	106	1269	-
Gorilla	21.9	4	216	863	10,352	-	-	-	-	-
Moline	94.2	8	310	1238	14,860	-	5	20	242	-

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
    a) FRA Track Class and operating speed
    b) Current operating speed
    c) Jointed or welded rail
    d) Rail weight
    e) Rail age
    f) Ballast conditions (type of ballast, depth, etc.)
    g) Tie age and condition (i.e., plate cut, split, etc.)
    h) Weight capacity
    i) Structure sufficiency data (capability of handling 286,000 pound cars)

Subdivision	***FRA Track Class***	***Current Operating Speed***	***Jointed or Welded Rail***	***Rail Weight***	***Rail Age***	***Ballast Condition***				***Tie Age***	***Tie Cond.***	***Weight Capacity***
						Type	***Depth***	***Age***	***Other***			
Chanute	2	25	Jointed	90	60+	Limestone	6 in	Varies	-	Varies	fair	286,000
Coffeyville	2	25	Welded	90	60+	Limestone	6 in	Varies	-	Varies	fair	263,000
Tulsa	2	25	Both	90	60+	Limestone	6 in	Varies	-	Varies	fair	263,000
Neodesha	2	25	Both	90/115	60+	Limestone	6 in	Varies	-	Varies	poor	263,000
Gorilla	2	20	Jointed	115	20	Limestone	6 in	Varies	-	Varies	poor	263,000
Moline	2	25	Welded	132	50+	Limestone	6 in	Varies	-	Varies	fair	263,000

8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

   SKOL maintains trackage rights on BNSF track from Winfield, KS to Wichita, KS. This can be referenced on attached SKOL Track Capacity Map. Segment offers SKOL interchange with Kansas & Oklahoma Railroad to add value to western Kansas shippers and provide future rail solutions.

9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?

   See attached SKOL Track Capacity Map.

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

    SKOL is committed to the communities we serve and we do not foresee abandonment of any track at this time.

11. Does your company make projections as to future growth in your business?

    Annual projections are completed and often times a three or five year outlook will be evaluated.

    d) If so, are these by tonnage or number of carloads?
    Projections are completed by carloads.

    e) If so, what is the basis for these projections?
    Projections are based on our customer input for planning purposes.

    f) What are your most recent projections for the next three years?

Year	2015	2016	2017
Projection	62,212	68,643	70,015

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

    SKOL maintains adequate locomotive power to pull our current 286,000 lb cars. In addition our connectivity with two sister railroads (Kansas & Oklahoma Railroad at Wichita, KS and Stillwater Central Railroad at Tulsa, OK) offers flexibility with locomotive power solutions.

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

    SKOL is evaluating track capacity upgrades on the following subdivisions Moline, Chanute, Coffeyville and Tulsa. A timeframe cannot be outlined at this time. We will prioritize projects based on our customers' needs and the consideration of operational efficiencies.

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

    Increasing our grain fleet could offer benefit to our operations and customer service. Currently we maintain a Central Region grain fleet and divide base on customer harvest feedback.

V & S RAILROAD

1. What are the top five commodities shipped on your railroad?

Commodities:	**Wallboard**	**Plaster**	**Scrap Metal**	**Fertilizer**	**N/A**

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.

   Not really. Fluctuations are accounted for by market prices, or change the pricing of a finished product. Example: If a price increase goes into effect in January, we will see a surge in shipments leading up to the price increase. Traffic will drop off quickly, then slowly regain previous levels.

3. What are your main locations for originating and terminating traffic?

   Originating: Medicine Lodge (manufacturing plant)
   Terminating: Attica (interchange with BNSF)

4. Is your railroad owned by a parent company? If so, which one?

   V&S Railway, LLC is a standalone company, but managed in parallel with other railroads.

5. What are your railroad's primary corridors? Feeder line corridors?

   Primary: Attica, to Medicine Lodge
   Feeder: None

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
   - a) Subdivisions and key segment route miles
   - b) Gross ton-miles per year
   - c) Number of slow orders
   - d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season
   - e) Total revenue
   - f) Percentage non-class I line revenue

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
   - a) FRA Track Class and operating speed
   - b) Current operating speed
   - c) Jointed or welded rail
   - d) Rail weight
   - e) Rail age
   - f) Ballast conditions (type of ballast, depth, etc.)
   - g) Tie age and condition (i.e., plate cut, split, etc.)
   - h) Weight capacity
   - i) Structure sufficiency data (capability of handling 286,000 pound cars)

     We are in the middle of a project to upgrade the line to Class II

Subdivision	Length (miles)	Number of Slow Orders	Average 263,000 lb Railcars Per				Average 286,000 lb Railcars Per			
			Week	Month	Year	Season	Week	Month	Year	Season
Column 1	21	Excepted	10	40	-	-	10	40	-	-

Subdivision	FRA Track Class	Current Operating Speed	Jointed or Welded Rail	Rail Weight	Rail Age	Ballast Condition				Tie Age	Tie Cond.	Weight Capacity
						Type	Depth	Age	Other			
Column 1	Ex.	10	10	112	-	Gran.	12”	-	-	5-80	poor	286K

8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

   No trackage rights except for interchange purposes.

9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?

   We are currently moving 286k cars, and through the State program making changes so that this is maintained for the next ten years.

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

    If the plant in Medicine Lodge were to be shut down, or economics made trucking more attractive.

11. Does your company make projections as to future growth in your business?

    Any projections would be tied to the projection of the building industry, or unforeseen markets (i.e. frac sand, oil, wind turbine projects, etc.)

    a) If so, are these by tonnage or number of carloads?

       carloads

    b) If so, what is the basis for these projections?

       N/A

    c) What are your most recent projections for the next three years?

Year	**2015**	**2016**	**2017**
Projection	**N/A**	**N/A**	**N/A**

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

    The answer is dependent on the number of cars and the speed at which you choose to travel. On very rare occasions, we will have to increase service, or leave cars behind.

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

    Already handle them.

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

    We run into car supply issues for a few months each year. The biggest threat to the railroad at this time would be the age of bridges, and the need for funding to repair them.

KANSAS CITY TERMINAL // KAW RIVER RAILROAD

1. What are the top five commodities shipped on your railroad? Kaw River Railroad (KAW)

Commodities:	Grain Products	Paper	Cement	Lumber	Plastics

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.
   Cement and lumber experience seasonality due to favorable weather for construction activity

3. What are your main locations for originating and terminating traffic?
   Originating: Kansas City, MO
   Terminating: Kansas City, MO
   Note: KAW is a handling carrier for BNSF.

4. Is your railroad owned by a parent company? If so, which one?
   KAW is a wholly owned subsidiary of Watco Companies. The railroad detail provided is referencing a lease rail line with BNSF Railway.

5. What are your railroad's primary corridors? Feeder line corridors?
   Primary: BNSF
   Feeder: BNSF

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
   a) Subdivisions and key segment route miles
   b) Gross ton-miles per year
   c) Number of slow orders
   d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season
   e) Total revenue
   f) Percentage non-class I line revenue

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
   a) FRA Track Class and operating speed
   b) Current operating speed
   c) Jointed or welded rail
   d) Rail weight
   e) Rail age -
   f) Ballast conditions (type of ballast, depth, etc.)
   g) Tie age and condition (i.e., plate cut, split, etc.)
   h) Weight capacity
   i) Structure sufficiency data (capability of handling 286,000 pound cars)

Subdivision	Length (miles)	Number of Slow Orders	Average 263,000 lb Railcars Per				Average 286,000 lb Railcars Per			
			Week	Month	Year	Season	Week	Month	Year	Season
Bedford	5	0	-	-	-	-	95	413	4958	NA
Kearney	16	0	-	-	-	-	7	30	358	NA

Subdivision	FRA Track Class	Current Operating Speed	Jointed or Welded Rail	Rail Weight	Rail Age	Ballast Condition				Tie Age	Tie Cond.	Weight Capacity
						Type	Depth	Age	Other			
Bedford	1	10 mph	Jointed	90-110	-	Granite/ Limestone	6 inch	2-5 yrs	-	10-15 yrs	Fair	286,000
Kearney	1	10 mph	Jointed	110	-	-	-	-	-	10-15 yrs	Fair	286,000

8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

    BNSF for interchange purposes only.

9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?

    If so, please send with completed questionnaire

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

    None at this time.

11. Does your company make projections as to future growth in your business?

    Yes.

    a) If so, are these by tonnage or number of carloads?

       Carloads

    b) If so, what is the basis for these projections?

       Our projections mirror Customer projections for the line.

    c) What are your most recent projections for the next three years?

Year	2015	2016	2017
Projection	5316	5475	5639

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

    All track is 286k capacity.

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

    Not at this time.

NEW CENTURY AirCENTER

1. What are the top five commodities shipped on your railroad?

Commodities:	**Soybean oil**	**Steel-**	**Lumber-**	**Acetic acid-**	**Plastic Beeds-**

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.

   NO

3. What are your main locations for originating and terminating traffic?

   Originating: Main yard track 8601

   Terminating: Main yard track 8601

4. Is your railroad owned by a parent company? If so, which one?

   No

5. What are your railroad's primary corridors? Feeder line corridors?

   Primary: None

   Feeder:

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
   a) Subdivisions and key segment route miles
   b) Gross ton-miles per year
   c) Number of slow orders
   d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season
   e) Total revenue
   f) Percentage non-class I line revenue

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
   a) FRA Track Class and operating speed
   b) Current operating speed
   c) Jointed or welded rail
   d) Rail weight
   e) Rail age
   f) Ballast conditions (type of ballast, depth, etc.)
   g) Tie age and condition (i.e., plate cut, split, etc.)
   h) Weight capacity
   i) Structure sufficiency data (capability of handling 286,000 pound cars)

Subdivision	**Length (miles)**	**Number of Slow Orders**	**Average 263,000 lb Railcars Per**				**Average 286,000 lb Railcars Per**			
			Week	**Month**	**Year**	**Season**	**Week**	**Month**	**Year**	**Season**
Column 1	6	0	4	150	1000-	-	3-	15-	250-	-

Subdivision	**FRA Track Class**	**Current Operating Speed**	**Jointed or Welded Rail**	**Rail Weight**	**Rail Age**	**Ballast Condition**				**Tie Age**	**Tie Cond.**	**Weight Capacity**
						Type	**Depth**	**Age**	**Other**			
Column 1	1-	10mph	Jointed	90&105	60yrs	Limestone	-	4yrs	-	4yrs	good	-

8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

   No

9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?

   No

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

    No

11. Does your company make projections as to future growth in your business?

    Yes

    a) If so, are these by tonnage or number of carloads?

    Number of carloads

    b) If so, what is the basis for these projections?

    Added businesses to our industrial park

    c) What are your most recent projections for the next three years?

Year	**2015**	**2016**	**2017**
Projection	**0-**	**0**	**500**

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

    Yes Sw900 and Sw1500

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

    Not at this time

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)

    No

WICHITA TERMINAL

1. What are the top five commodities shipped on your railroad?

Commodities:	**Wheat-**	**Flour**	**Soybeans**	**Scrap**	**Soybean Oil**

2. Is your business affected by seasonal differentiation in products? If so explain to what extent.
   Yes. Wheat is seasonal. We will typically get most of our wheat for Ardent Mills and Bartlett from May-Aug.

3. What are your main locations for originating and terminating traffic?
   Originating: Wichita
   Terminating: Wichita
   I have no information as to where the cars originate / terminate on the BNSF / UPRR.

4. Is your railroad owned by a parent company? If so, which one?
   Yes. BNSF and UPRR

5. What are your railroad's primary corridors? Feeder line corridors?
   Primary: N/A
   Feeder: N/A

6. What is your railroad's operating characteristic by subdivision and key segments within subdivisions? (If you have more subdivision, you can add more Rows)
   a) Subdivisions and key segment route miles – We have no named subdivisions.
   b) Gross ton-miles per year - Unkown
   c) Number of slow orders – All tracks are either 5 or 10 MPH. No slows. We pull it out of service if not good for posted speed.
   d) Average number of railcars by weight (263,000 or 286,000) per week, month, year and season – N/A
   e) Total revenue – We get no revenue. All revenue collected by owning rail companies.
   f) Percentage non-class I line revenue

7. What are the infrastructure characteristics of your class III by subdivision and key segments within the subdivsions? (If you have more subdivision, you can add more Rows)
   a) FRA Track Class and operating speed – Class 1 and Excepted – 5 mph except 10 mph on lead
   b) Current operating speed – 5 mph except 10 mph on lead
   c) Jointed or welded rail - jointed
   d) Rail weight – 90 to 115 lbs
   e) Rail age – new to 80 yrs old
   f) Ballast conditions (type of ballast, depth, etc.) – 2" ballast – 6 to 12 inches in depth
   g) Tie age and condition (i.e., plate cut, split, etc.) – new to 15 years old
   h) Weight capacity – 243 ton (not excepted track)
   i) Structure sufficiency data (capability of handling 286,000 pound cars)
      All tracks rate to 143 ton

Subdivision	***Length (miles)***	***Number of Slow Orders***	***Average 263,000 lb Railcars Per***				***Average 286,000 lb Railcars Per***			
			Week	***Month***	***Year***	***Season***	***Week***	***Month***	***Year***	***Season***
Column 1	10	0	-	-	-	-	-	-	-	-

Subdivision	***FRA Track Class***	***Current Operating Speed***	***Jointed or Welded Rail***	***Rail Weight***	***Rail Age***	***Ballast Condition***				***Tie Age***	***Tie Cond.***	***Weight Capacity***
						Type	***Depth***	***Age***	***Other***			
Column 1	1	5 to 10	Jointed	90 – 115	0-15	2”-	6-12 in		-	0-15-	-	286,000

8. Does your railroad have trackage rights on another railroad's track or does another railroad have trackage rights over your railroad? If so what segments are shared?

   We have trackage rights on BNSF and UPRR. No one has rights on WTA tracks.

9. Do you have a map showing the exact segments or Sub-Divisions that you'd willingly share with us that show 286,000 lb railcar handling capacity; bridge structural issues; geometric issues; track speed; trackage rights?

   N/A

10. Are there any scenarios (including economic impacts) under which you could foresee the abandonment of your railroad, or specific line segments?

    No

11. Does your company make projections as to future growth in your business?

    No. BNSF / UPRR make marketing projections.

    a) If so, are these by tonnage or number of carloads?

    b) If so, what is the basis for these projections?

    c) What are your most recent projections for the next three years?

Year	**2015**	**2016**	**2017**
Projection	**-**	**-**	**-**

12. Do you have an adequate number of locomotives with the power to pull fully loaded 286,000 lb cars?

    Yes

13. Does your company have any plans to increase track capacity to handle fully loaded 286,000 lb railcars (or along greater lengths of track)? If so, what track segments? Do you have a timeframe during which you hope to complete these upgrades? Can you prioritize these projects?

    Adding one storage track of about 12 car lengths in 2017.

14. Are there other issues that your railroad experiences that you feel hamper your operations and/or affect customer service? (i.e. car supply shortage)