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Russia's Next Generation Railcars

An Interactive Qualifying Project Report

Submitted to the Faculty of the
WORCESTER POLYTECHNIC INSTITUTE
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Sponsoring Agency:

Brunswick Rail

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Abstract

Brunswick Rail must replace nearly 8,000 railcars as they reach the end of their service life, with either existing standard railcars or New Generation Railcars (NGRs). Russia’s railcar fleet as a whole faces a similar dilemma. We determined the potential effects of NGRs on railcar leasing by conducting a cost-benefit analysis and through discussions with industry experts. While NGRs could be beneficial to the rail industry, Brunswick Rail will find purchasing these railcars difficult due to the current economic environment.

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Authorship

Angelica Berezenkova, Brianna Fogal, Henry Hoffman, Egor Iakovlev, Maria Petrova, and Corin Rypkema have all contributed to the completion of this Interactive Qualifying Project. Specific contributions of each person can be found below.

Angelica Berezenkova was present at the interview with John Winner, translated many Russian news reports and articles, and was the primary source of information about France and Brazil.

Brianna Fogal was present at all interviews, wrote the appendices and all sections involving objectives one, two, and six, and edited and formatted all sections of the report.

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Maria Petrova was present at the interview with Lilia Lavrova, translated many Russian articles, and was the primary source of information for Australia and China.

Corin Rypkema was present at all interviews, wrote all sections involving objectives three, four, and five, and edited and formatted all sections of the report.

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Executive Summary

Russia's railcar fleet is starting to age, and many railcars need replacement. Brunswick Rail, along with other leasing companies and industry players in Russia, face a decision between replacing aging railcars with new, but old style railcars or with newly produced, innovative railcars. Russia depends on railcars for transporting a large majority of its freight, so the problem requires an urgent solution. The situation is complex as the Russian economy continues to move in a somewhat negative direction, and key factors such as government policy and environmental impact need consideration.

The goal of this project was to conduct a comparative analysis and evaluation of Russia's new generation railcars (NGRs) and determine whether it is feasible or advisable for Brunswick Rail to buy them as replacements for some of its aging railcars. For this project, we focused on gondolas. In order to accomplish this goal, we met the following objectives. First, since new generation railcars are still mostly an idea, we developed a concrete definition of what NGRs are. Second, we identified important mechanical factors and differences among NGRs in Russia and their counterparts throughout the world. Third, we determined the environmental impact of NGRs versus the old railcars. Fourth, we determined the financial impact of purchasing NGRs for Brunswick Rail. Fifth, we identified government policies that impact these NGRs. Finally, we compared different types of railcar leasing business models.

We met these objectives through extensive library and archival research, key informant interviews, comparative technical analysis, environment impact analysis, and financial modeling. Interviews with railcar industry experts Lilia Lavrova, Pavel Ivankin,

John Winner, and Marcus Montenecourt not only provided us with their opinions and suggestions, but also helped us better understand the industry as a whole.

We compared key mechanical features among NGRs, we discussed the need for NGRs in Russia, we determined the environmental impact NGRs would cause, we determined the financial feasibility of purchasing NGRs for a leasing company such as Brunswick Rail, and finally we identified the potential impact of government policy changes.

Based on our analysis we drew the following important conclusions:

Better bogie design and larger body volume are the most important factors in NGR design. Larger capacity by weight (about 8.9%) and by volume (4.5%) allows for a reduction in terms of the number of railcars needed. This leads to less congestion in the system and less wear on tracks.

The longer service life of NGRs makes them a financially appealing option. The longer lifespan of NGRs spreads out servicing costs over a period of 10 more years than with original generation railcars. Purchase of NGRs by Brunswick Rail should wait until the entire maintenance profile of a NGR has been established and leasing rates have recovered to previous levels.

Subsidies play a large role in purchasing new railcars. Currently government provided subsidies play a major role in purchasing a NGR by effectively decreasing the price by 130,000 rubles or reducing the overall cost by 6.2%. This subsidy comes in the form of a reduction in the interest paid on the purchase of a NGR during its first year.

The operation of NGRs does not result in a significant reduction in fuel usage. Since trains are already a very efficient form of transportation in terms of fuel consumption, switching to NGRs does not lead to a large decrease in fuel used.

Significant reductions in CO2 emissions from railcar production can be achieved through NGRs. The longer service life of NGRs results in 29% less carbon emissions from railcar production over the next 65 years over old railcars. The use of NGRs is the socially responsible choice.

We have also made several recommendations for Brunswick Rail and for continued research in this field. Note that these recommendations come from an academic, limited financial and social, contextual analysis and should only be used for further study and consideration.

We recommend Brunswick Rail wait to purchase NGRs. The company is currently undergoing a significantly stressful period, and the market rate for leasing is much lower than previous levels. Once the leasing market returns to a better rate, NGRs should seriously be considered for purchase due to their superior mechanical characteristics and benefit to the industry.

We recommend further research in NGR maintenance and loan specifics to complete the cost-benefit analysis. The cost for the full service profile of a NGR is only an estimation. Complete pricing for maintenance will be available within the first couple of years of operating NGRs. At that point the full financial feasibility of purchasing NGRs will be able to be calculated.

We recommend Brunswick Rail place the cost of maintenance on the customer. Maintenance costs, especially for NGRs, are a large portion of costs and

and are volatile in nature. Brunswick Rail will avoid risk by having the customer pay for all maintenance.

We recommend further research into Australia's rail industry and its government policies to determine possible better railcar leasing practices and general improvements. Australia's rail industry is similar to Russia's in that it is owned by the government and goods need to travel long distances. Australia is also currently using the most advanced gondola design in the world, reaching 44 tonnes per axle.

Chapter 1. Introduction

The railroad system plays a vital role in the transportation of goods, resources, and people across short and great distances all around the world. In Russia this is overwhelmingly true (Gray, 2013). The Russian economy heavily depends on railways because there is no feasible alternative transport due to the extreme climate, large quantities of freight, cost efficiency and, most critically, long distances. This has led to over 87% of freight turnover being transported by rail (United Wagon Company, 2015c). Due to many railcars reaching the end of their service lives and the Russian economy currently in a decline, the rail industry in Russia must decide whether or not to invest in new, expensive railcars.

Brunswick Rail (2014b), a leading railcar leasing company in Russia, has not been immune to the recent economic situation. Since Brunswick Rail leases railcars to many industrial and transportation businesses across Russia, those companies' actions in turn affect a large number of people. Russia's rail industry, along with Brunswick Rail, needs to make a decision between using and producing old generation railcars or investing in new, innovative railcars. Brunswick Rail needs to determine which new generation railcars to purchase, if any, as well as the best business model for leasing these innovative railcars.

United Wagon Company, Uralvagonzavod, Altaivagon, and PromTractor Wagon are four of the top ten railcar producers in the CIS (United Wagon Company, 2015b). Significant hype exists within the industry about the new and innovative railcars that promise to carry larger loads and have a longer service life than the old railcars, and some analysis has been completed in order to prove this (Russian Railways, 2015a). Like all large systems, rail innovation happens in stages; other countries throughout the world have already moved onto, or in some cases past, the capabilities of the railcars that Russia considers to be innovative.

No formal research has been completed to see if the interest in these new generation railcars is justified or will result in an improvement to the industry. Making and using the new railcars could have a large impact on not only Brunswick Rail's financial outlook and current position, but also on the environment and economy of Russia as a whole. Brunswick Rail would like to know how to proceed in this new economic and technological context.

The goal of this project was to construct a comparative analysis of railcar innovations to assist Brunswick Rail in developing their railcar fleet and the future of their company. Our objectives were to: define what a new generation railcar (NGR) is, identify mechanical and technical differences among these NGRs, determine environmental and economic impact of NGRs, identify government policy that impacts NGRs, and determine differences in railcar leasing business models and technical trends among Russia, the rest of Europe, Australia and North America. To accomplish these objectives we conducted interviews with various rail industry experts, analyzed data from Russian Railways and conducted a comparative analysis of all NGRs. Our findings not only give development ideas and opportunities to Brunswick Rail, but potentially to other railcar leasing companies around the world in need of future improvement.

Chapter 2. Background

Freight transportation by rail is one of the most common modes of transportation of goods. This is overwhelmingly true in Russia, where railways transport 87% of the freight (United Wagon Company, 2015c). This chapter discusses in detail the many aspects of the rail freight transportation industry. First, we clarify why the rail industry is important for our daily lives. Second, we define the players in this industry and describe their roles. Third, we discuss the various types of railcars and their purposes. Fourth, we define the general terms used in policies related to rail industries. Finally, we discuss how the rail industry in Russia operates and two major contributors of the system.

2.1 The Importance of the Rail Industry

As early as the 18th century, railroads were built in Great Britain to transport coal from mines to factories (Train History, 2015). The rail industry grew from these simple railway networks of horse drawn carts on wooden tracks, to a world network of more than one million kilometers of track on which railcars transport more than 40% of the world's total goods (World Bank Group, 2015). Today, large cities around the world would not be able to properly function without rail passenger transportation to carry millions of people to and from work every single day. Aside from popularity of use, rail transportation is a more cost effective way to transport freight, especially over long distances (Network Rail, 2013). To transport one tonne of goods, a train can travel 246 miles on one gallon of fuel, whereas a truck can only travel 88 miles. Rail transport is also more environmentally sound, emitting only a third of the carbon dioxide that a truck does per tonne-kilometer. Technology is advancing every year, inventing more efficient, cost effective locomotives and railcars to further develop one of the world's already most used transportation systems.

2.2 Players in Rail Freight Transportation

The rail freight industry is large and complex (Coyle, 2006). Organizations and groups exist for every facet of the industry, including the railroad infrastructure owners, shippers, operators, lessors, and others who provide needed services. In this section, we will discuss notable players within the industry and how they integrate into the entire system.

2.2.1 Railcar Lessors

According to Richard Sultanov (personal communication, April 17th, 2015) of Brunswick Rail, railcar leasing provides logistics, management and maintenance services for industrial businesses and rail operators. These combined services allow railway operators and producers to focus on their core business of moving goods and allow leasing operators to focus on managing the capital equipment needed to transport goods.

Railcar leasing is utilized to make the transportation of manufactured goods, oil, stone, people and many other resources more efficient and cost effective for businesses everywhere (Brunswick Rail, 2014d). Both operators and businesses alike can lease railcars on long-term or short-term contracts to properly accommodate for the size of deliveries.

Some railcar leasing companies not only have railcars to lease but also have railcars to purchase via a leasing-to-own contract (The Andersons Inc, 2015). These companies have the resources available to service the railcars on a regular basis and whenever needed. They also have the ability to provide the customers with their preference of railcar brand because of the company's connections with multiple railcar manufacturers.

2.2.2 Shippers and Operators

Freight by rail is used when an organization holds an abundance of goods in one area that is separated over a large distance from another area that is lacking these goods (Coyle, 2006). This definition leads to the conclusion that the demand for freight is not set by the actions of the transporter, but by the consumers of goods and the businesses selling these goods. Such a distinction seemingly leaves the transportation industry at the whim of the greater economy. Producing businesses need to choose which transportation method to use to deliver products to the consumers. This creates competition among transportation services to obtain the business of these producing companies. Thus, each company must strive to be as efficient as possible in order to compete successfully. Coyle noted that five factors, transit time, reliability, accessibility, capability and security, are the key service differences among rail operators. Since shippers and consumers, and not the railroad system itself, set the demand for freight, the industry must make improvements in order to accommodate this. Optimization of practices and equipment will lead to more efficiency in use and thus more business and higher profits.

2.2.3 Railcar Owners

The two most common types of railcar owners are private owners and government owners (Richard Sultanov, personal communication, April 17th, 2015). Private owners can be lessors, operators and private companies. For example, a private company that owns railcars could be a coal mining company that made a private railway network to transport their mined coal to a power plant. Government owned railcars typically either are leased to companies or are operated only by the government.

2.2.4 IT & Maintenance

The rail industry uses several supporting sectors to maintain efficiency and reliability. Two notable supporting sectors are communication systems provided through information technology and railcar maintenance (Coyle, 2006, p.373).

Over time, railcars break down and degrade to the point where maintenance is necessary (Hicks, 2015). Hicks mentions several factors that cause a railcar to require maintenance: “defect in manufacture, … damage during car loading or unloading, wheels, braking system, car body [sic] damage and much more” (¶ 3). When damage becomes a matter of public safety, governmental bodies mandate through policy that railcars be fixed (GATX, 2015). Leasing companies may stipulate in a contract that a railcar is returned in the same condition that it was delivered.

Both singular and bidirectional communication systems allow for better tracking of resources and planning for their use, through the use of satellite-based global positioning systems (GPS) and radio frequency (RF) transmitters (Coyle, 2006, p. 373). Railcars with other transport modes combine communication systems to create a complete network. Positioning information obtained by GPS can be combined with container health information, such as temperature of goods, and then pushed by RF to a datacenter. Such communication systems allow adopters to better allocate resources and decrease the amount of equipment needed.

2.3 General Overview of Railcars

Since railways transport many kinds of goods, there are several different types of railcars used (Union Pacific Railroad Company, 2015). These are highlighted in Table 1.

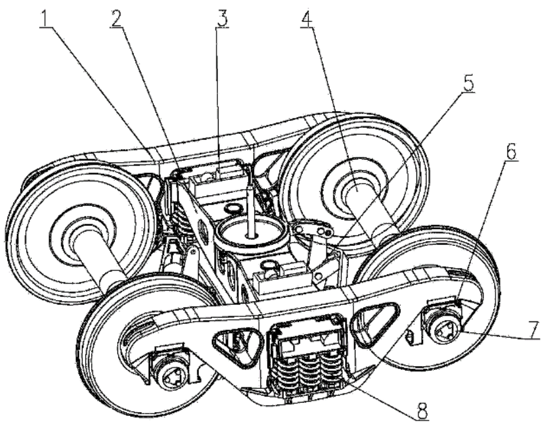
Table 1: Types of Railcars

	Boxcars, the most common type of railcar, transport crated freight of all kinds.
	For dry bulk goods, covered hoppers load product from the top and discharge it from the bottom. These carry goods such as coal, sugar, grain, and anything that needs protection from the weather.
	Flatcars transport large freight containers and also bulky products that would not be damaged by the weather.

	Refrigerated boxcars transport perishable freight such as fruits and vegetables in a temperature controlled environment.
	Tank cars ship any variety of liquid or compressed gas.
	Finally, gondolas transport loose bulk goods such as lumber, metal, and coal in uncovered cars. This is Brunswick Rail's (2014i) most used railcar.

2.4 Bogies

The typical freight rolling stock car utilizes four sets of wheels with corresponding axles (Railway Technical, 2014). Two wheel sets combine into a larger superstructure called a bogie, with one bogie at each end of the railcar. The bogies and wheels allow the train to move along the length of the rail. The wheel sets traditionally are held rigidly in the same position, with the wheels themselves being curved to allow the train to follow turns. This is shown in Figure 1.



1. Two side frame assemblies
2. Bolster assembly
3. Two side pedestals
4. Front and rear wheel pair assembly
5. Basic braking device
6. Roller bearing adapters
7. Bearing assemblies
8. Spring suspension devices

Figure 1: Bogie Diagram

(Sun, Xu, Wang, & Li, 2013)

2.5 Policy of Governments in Rail Systems

Government policy and regulation within transportation systems is important in order to keep demand, environmental impacts, and military concerns controlled (Kane, 2002). Regulations present an effective method to maintain competitiveness and consistency within a transportation system. More importantly, regulations impact industry members’ safety along with external social and environmental effects.

Good policy decisions and regulations have long lasting effects (Caves, Christensen, & Swanson, 2010-2011). Caves writes, “Finally, in looking back over the last three decades, we note that the experience of the railroad industry appears largely free of the moral hazards that have led to calamities in other ‘partially deregulated’ industries (e.g., savings and loans, banking, and the California electricity market). This is a tribute to the policy architects for the railroad industry” (p. 31). An example of a policy that has had lasting effects, in Russia, there is a regulation that requires all bogies to be completely disassembled and rebuilt every five years. This regulation has effects on the industry, which will be discussed later in the report.

2.6 Rail Industry in Russia

With over 85,000 kilometers of track, the rail network in Russia is the third largest in the world (Railway Technology, 2014). Though the United States and China have stayed ahead in overall kilometers of track, Russia is the owner of the longest railway line in the world: the Trans-Siberian Railway (9,289km). Russia's active rail network not only spans the entire eleven time zone length of the country, but also directly connects to the European and Asian national railway systems. However, China and most of Europe use a 1435mm rail gauge, or the distance between the tracks, whereas Russia uses 1520mm. This 85mm (3 inches) difference may not seem significant, but without the correct gauge, the railcars cannot operate on the different track. The focus of this section is on Russian Railways, the monopoly operator of Russia's railway network, and Brunswick Rail, the sponsor of this project.

2.6.1 Russian Railways

Russian Railways (2015b), or RZD, is a government owned railroad operator under the government of the Russian Federation. The company was created as a result of calls for reforms to the system in 2003 to separate the Ministry of Railways from operating and providing rolling stock. Today, shippers fill their railcars with the goods to be transported, pay the transportation fee and RZD transports the goods to their destinations. RZD is the primary owner of locomotives in Russia and owns the entire rail track system besides small, private sections that connect entities such as factories or mines to the mainline.

2.6.2 Brunswick Rail

Between the years 2011 to 2013, Russia's railcar industry turnover in terms of railcars replaced was third in the world, and Russia was second in terms of number of railcars in use (Brunswick Rail, 2014b). In such a lucrative and competitive market, Brunswick Rail has been the leading operating railcar lessor in Russia since the year 2004. Brunswick Rail owns a fleet of over 25,000 high quality railcars that it leases to customers throughout Russia. Brunswick Rail leases railcars to a variety of sectors such as transportation, oil & gas, timber and many more.

Brunswick Rail (2014e; 2014h) was founded in 2004 as the first private railcar leasing company in Russia after the privatization reforms of rolling stock in 2003. Brunswick Rail's major investor since December 2010 has been VTB Investment Management. Brunswick Rail receives minor investments from private investors in Russia and around the world due to its strong track record of successful operations and attractive market.

Brunswick Rail (2014i) leases several different kinds of railcars, with gondolas composing the majority of the fleet. The division of railcar types that Brunswick Rail owns can be seen in Figure 2.

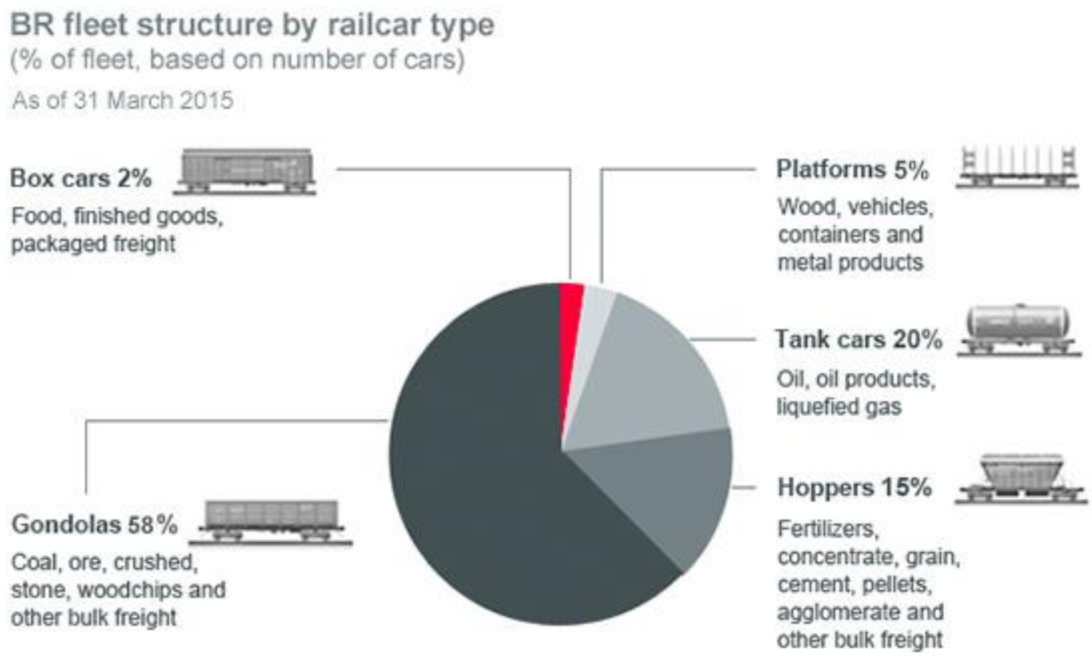


Figure 2: Brunswick Rail Fleet Structure by Railcar Type

(Brunswick Rail, 2014i)

Currently Brunswick Rail's (2014j) fleet of railcars has an average age of 5 years, which in comparison to the rest of Russia's railcars, is considered young. All railcars are insured by Brunswick Rail (2014j) at its own expense for damage or total loss, and all completed maintenance is arranged for and at the expense of the client. Brunswick Rail's clients categorized by industry can be seen in Figure 3.

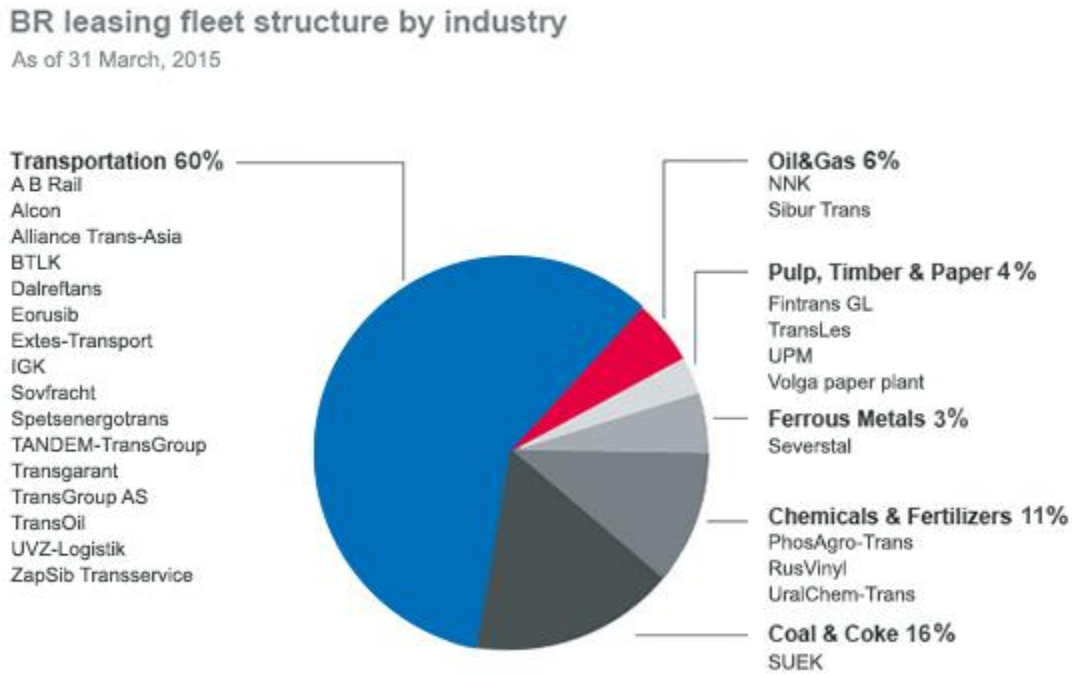


Figure 3: Brunswick Rail Client Breakdown by Industry

(Brunswick Rail, 2014a)

Information regarding leasing and operational costs and railcar age will be presented later in Chapter 4. For more information about our sponsor, please refer to Appendix A.

2.7 Summary

In this chapter, we have described the railcar leasing process and the features of Russia's rolling stock. Each associated part of the railcar leasing business profoundly affects the way the industry works. Our methodologies presented in the next chapter utilize the prior research into next generation railcars and apply them to find answers regarding the usability and feasibility of these railcars.

Chapter 3. Methodology

The goal of this project was to construct a comparative analysis of railcar innovations to assist Brunswick Rail in choosing the composition of their future railcar fleet. Specifically we investigated gondola New Generation Railcars (NGRs) made in Russia with respect to key mechanical, environmental, financial, governmental, and business development factors.

Our objectives were:

- Define the New Generation Railcar
- Identify important mechanical factors and differences between NGRs in Russia and their counterparts throughout the world.
- Determine the environmental impact of NGRs
- Determine cost of purchasing and maintaining NGRs
- Identify government policies that impact NGRs
- Identify and compare railcar leasing business models in Russia, Europe, Australia, and North America

To better investigate the full picture of the project, we created a framework for analysis that used mechanical, financial, environmental and governmental factors. Brunswick Rail was mostly interested in the mechanical and financial implications of NGRs and our engineering opinion of them, so we decided that all mechanical and financial data were to be gathered with a focus on how they would impact the company or any other railcar leasing venture in Russia. Environmental impacts were considered from a macro-level perspective, using data collected on the railcar industry as a whole and not just the lessors. This is illustrated in Table 2.

This chapter discusses how the objectives were achieved using various methods, including data collection and interviews. All interviews were conducted in accordance with Worcester Polytechnic Institute's Institutional Review Board guidelines.

Table 2: Project's Analytical Framework

Financial	**Government Policy**
Cost Benefit Analysis Daily Running Cost Maintenance	Tariffs, Discounts Incentives Who is affected
Environmental Impact	**Mechanical**
Petroleum Saved Carbon Emissions from production of railcars	Tonnes/Axle Capacity Life Expectancy

3.1 Definition of NGRs

In order to define what innovations within the railcar industry would classify a new railcar as next generation, we contacted and interviewed key players and experts in the industry, namely Lilia Lavrova, Pavel Ivankin, John Winner, and Marcus Montenecourt. The most practical strategy used to obtain the interviewees' true opinions was to utilize open-ended questions. These interview protocols can be found in Appendices C-F.

To begin, we interviewed Lilia Lavrova, Deputy Head of Corporate Communications for United Wagon Company (UWC) when we attended the Railcar EXPO 1520 in Moscow. Tikhvin, a railcar manufacturing subsidiary of UWC, produced the largest amount of gondolas in 2015 for Russia. Ms. Lavrova was able to provide us with information that helped us to define what a NGR really is. The summary of Ms. Lavrova's interview can be found in Appendix B.

Pavel Ivankin, before joining Brunswick Rail as Managing Director of Business Development, worked at Russian Railways as Assistant to the President. He is viewed as an expert on NGRs at Brunswick Rail and provided us with additional information. The interview protocol and summary of Mr. Ivankin's interview can be found in Appendix E.

John Winner, a new railcar technology expert who has worked in the transportation industry for 30 years and has completed research projects for Brunswick Rail, works for Harral Winner Thompson Sharp Klein (HWTSK), a US based transportation consulting firm. He has completed projects for companies globally, including on new generation railcars in Russia. Information given by Mr. Winner helped us to refine our definition of what a NGR is. His interview protocol and interview summary can be found in Appendix C.

Amsted Rail, an American railcar equipment manufacturer, supplies the world with 1.3 million railcar wheels, an innovative bearing design, and produces the innovative motion control bogie. At the Russian office of this company, we interviewed Marcus Montenecourt, Managing Director of Amsted Rail's operations in the Russian Federation and CIS. Since Amsted Rail's motion control bogie design is currently being tested by Tikhvin to be used within NGRs, Mr. Montenecourt was able to provide his professional opinion regarding what a NGR consists of. His interview protocol and interview summary can be found in Appendix D.

3.2 Identify Important Mechanical Factors and Differences Among NGRs

Mechanical factors are the basic physical specifications of the railcars given by the company when that railcar is being produced. These mechanical factors and bogie design are the elements of a NGR that make it innovative. In order to easily identify these differences, the mechanical specifications for each railcar were collected into a table. Some of these key specifications for the mechanical parameters for the railcars were gathered in person at the biennial Commonwealth of Independent States rail exposition and conference, EXPO 1520. The companies that we received data from at the expo were Tikhvin and UVZ. These came in the form of data sheets provided at technology demonstration booths, visual inspection of railcars, and discussion with company representatives. These data were collected and organized into a spreadsheet that was later combined with data from PromTractor-Wagon and Altaivagon. We did not visit these companies at the expo, so data were later obtained from the companies' websites.

We were able to identify the most innovative and significant mechanical specifications of new railcar technology from around the world. This information was obtained through interviews with Marcus Montenecourt of Amsted Rail and John Winner, whose interview protocols and summaries can be found in Appendices D and C, respectively. These two experts were used because of their active involvement in world railcar technology development and analysis.

3.3 Determine the Environmental Impact of NGRs

As part of corporate social responsibility, Brunswick Rail has maintained an interest in how the use of the new railcars would affect the environment. The first method of determining the environmental impact through software did not produce satisfactory results, so a second, approach was taken.

Originally, we planned to use Carnegie Mellon University's Economic Input Output Life Cycle Analysis tool (Carnegie Mellon University, 2015). The software would have allowed us to obtain a worldwide perspective into how the replacement of the old railcars with new innovative ones would affect the economy and the environment. However, the tool does not include Russia as a country that it can model. After significant effort to create a world model via comparison with other available countries' data, we decided that the differences among countries economic models within the tool were too great and a different approach was needed. The original analysis and explanation has been included in Appendix J, K, and L in case it should prove useful at some point.

After the decision that the world view comparison using EIOLCA was not going to produce satisfactory results, we looked into other methods of obtaining a general idea of the environmental impact from the replacement of old railcars with new ones. The solution that we arrived at was a life cycle assessment and an investigation into energy use during operation. The first method we used was to look at the life cycle of a railcar. This is normally a very complicated process; however, since most of each railcar is made of the same material, steel, a simplified approach proved to be useful. For this analysis, we gathered expected replacement data for old railcars from Russian

Railways and data on the weight and kind of material each NGR is made from. The second approach, to estimate energy use, faced significant hurdles, since we found most of the operational data about Russia's rail operations is kept private by Russian Railways. We contacted Dr. Robert Traver, an environmental science professor at Worcester Polytechnic Institute, to obtain his opinion on how to make such an assessment. He suggested an assessment of the gallons of gasoline used by the new generation railcars compared to the old generation railcars. We were able to obtain enough information regarding the mechanical dynamics of the NGRs to create a solid estimate of the impact on fuel usage for each type of railcar.

3.4 Financial Analysis

Brunswick Rail wanted to know the financial feasibility of adopting NGR railcars into their fleet. A financial analysis was completed using a standard cost-benefit analysis model (Duff, 2015). We gathered relevant data from several sources including direct company information, private market analysis and publically available data. Expense factors included the initial cost, maintenance costs and time between service requirements. Benefit factors consisted of expected leasing rates for the present and future for each railcar, along with discounts on tariffs, subsidies from the government and scrap value from old railcars.

3.5 Identify Government Policies Related to NGRs

Policies adopted by the operators of railroads and by the governments under which they operate have a large effect on the industry as a whole. We obtained the relevant policies through interviews with Pavel Ivankin, Marcus Montenecourt, and John

Winner (interview summaries can be found in Appendices E, D, and C, respectively.) With Mr. Ivankin's expertise and background in the Russian Railways system, Mr. Monenecourt's experience on the Board of Directors of the American Chamber of Commerce in Russia and 20 years of rail industry experience, and Mr. Winner's knowledge as presented in his government policy reports on Russia, these interviews provided us with the necessary policy context that we needed to determine how policies could impact the adoption of NGRs. Empirical data augmented the interviews by calculating money saved by operators of NGR railcars within Russia due to the various tariff discount programs put in place by the government.

3.6 Determine differences in railcar leasing business models

Brunswick Rail offers two types of leasing services: a customer can lease the railcar for a certain amount of time or the customer can pay for the transportation service. Since Russian Railways has a monopoly over the rail industry, Brunswick Rail's options for expanding their business are limited. Because of this, our sponsors wanted us to identify business models used by railcar leasing companies in other parts of the world and determine the services offered. To accomplish this objective, we interviewed several experts on the global railcar industry including John Winner and Marcus Montenecourt, as shown in Appendices C and D, respectively. From both of these interviews, we obtained information about several successful businesses in China, the United States, Europe and Australia and how the rail industries in these countries operate. To further determine the services offered by these companies and the railcars that they are operating, we visited each company's website.

3.7 Summary

Once we had completed all interviews, collected mechanical specifications of NGRs, collected financial reports and railcar statistics, we were able to begin the analysis of all of our data. The analysis and overall results of this research are explained in the following chapter.

Chapter 4: Results and Analysis

The results of our research were designed to make useful predictions as to what is next for railcars in Russia in order for the industry as a whole to make key financial decisions, enhance policies and continue to move towards an efficient freight rail system to better serve the people of Russia. In this chapter, we discuss our results and provide analysis of the data collected through the methods mentioned in the previous chapter. Limitations of the data are also discussed and should be kept in mind when considering our findings.

4.1 Definition of a New Generation Railcar

As a basis for the rest of our research, we interviewed several experts on innovations within the railcar industry. To our surprise, there was overwhelming agreement on the definition of what a new generation railcar is. We asked the same question to each expert interviewed: innovation in the rail industry has taken many forms; what is your idea of a new generation railcar? All experts mentioned the same five factors: new bogie design, increased railcar volume, increased payload capacity, increased service life, and a decrease in maintenance frequency.

4.2 Importance of Mechanical Factors

Several Russian manufacturing companies' currently produce railcars with the features discussed by the experts. Each model of railcar has slightly different mechanical characteristics. A chart of the most relevant mechanical specifications can be seen in Table 3.

Table 3: New Generation Railcar Mechanical Factors Specifications, By Company and Model Number

Producer:	Tikhvin	Tikhvin	Tikhvin	UVZ	PromTractor	Altaivagon
Model #	12-9853	12-9937	12-9869	12-196-01	12-1304	12-2143 (42)
Bogie Model #	18-9855	18-9855	18-9855	18-194-1	18-9836	18-194-1
Payload Capacity	75t	75t	77t	75t	75t	77t
Tare Weight	25t	25t	23t	24t	24.5t	23t
Axle Load	25t	25t	25t	25t	25t	25t
Body Space	88 m^3	92 m^3	92 m^3	88 m^3	88 m^3	94 m^3
Service Life	32 yrs	32 yrs	32 yrs	32 yrs	32 yrs	32 yrs

According to Table 3, each railcar manufacturer provides mechanical specifications for each model of railcar. Each railcar has a model number that the manufacturer assigns, and each type of railcar has a specific number associated with it. For instance, we focused on the new generation gondolas that are being manufactured, and these model numbers begin with 12, as shown above. Following the model number is the bogie model number; this number always begins with 18. Next is the payload capacity; this number defines how much weight the railcar can hold, excluding the weight of the railcar and bogie itself. The tare weight is the empty weight of the railcar and bogie, and the axle load is the number of tonnes each axle can handle. Next, the body space is the volume of the railcar in cubic meters. Finally, the service life is the number of years the railcar can be operated before it needs to be replaced.

Each of these new generation gondolas are similar even though they are produced by different manufacturers. All NGRs have an axle load of 25 tonnes because each manufacturer is using a similar bogie design, the Barber S-2-R. Also, each railcar has a service life of 32 years, which is a 45% increase from an OGR. The rest of the factors vary only slightly. The railcar experts confirmed that in order for a railcar to be named innovative, it must have a payload capacity of at least 75 tonnes which is an increase of 8.9% over the old generation railcar. The 75 tonne requirement for payload capacity is achieved by each of these gondola models and is even surpassed by Tikhvin model 12-9869 and Altaivagon model 12-2143 at 77 tonnes.

According to Brunswick Rail's (2014g) New Generation Railcar report, a body volume of 98-100 m^3 is considered to be innovative. However, the only railcar expert to mention the larger volume was Pavel Ivankin, an employee of Brunswick Rail. There are currently no NGRs being produced in Russia with volumes greater than 98m^3, but all NGRs are 88 m^3 or more, with the largest being Altaivagon's 12-2143 model at 94 m^3. This marks an increase of an average of 4.5% from the old generation railcars.

Although in Russia these advances are impressive, Russia's railways are 15 years behind the United States and Australia. According to John Winner, new railcar technology expert, some gondolas in the United States have a payload capacity of 139 tonnes and in Australia, an axle load of 44 tonnes per axle.

4.3 Railcar Replacement Needs in Russia

The need for replacement of the railcars comes from the aging of Russia's fleet of freight railcars. The effective age limit of the older generation railcars is 22 years (United Wagon Company, 2015a). This means railcars produced on or before 1993 are being used on service life extension agreements via recertification with Russian Railways. As seen in Figure 4, there are two significant groups of railcars, specifically gondolas, produced. The oldest group was produced in the late 1980s before the collapse of the Soviet Union, and the newer group formed after the privatization reforms in 2003. The railcars that need replacement are all railcars produced during the Soviet Era. By adding the railcars produced for each year after 1993, we determined the number of railcars that need replacement is 135,632. This is 42% of the total 325,408 railcars in the system (see Appendix H). Brunswick Rail compiled the data for the following histograms (Figures 4-9) in September 2015.

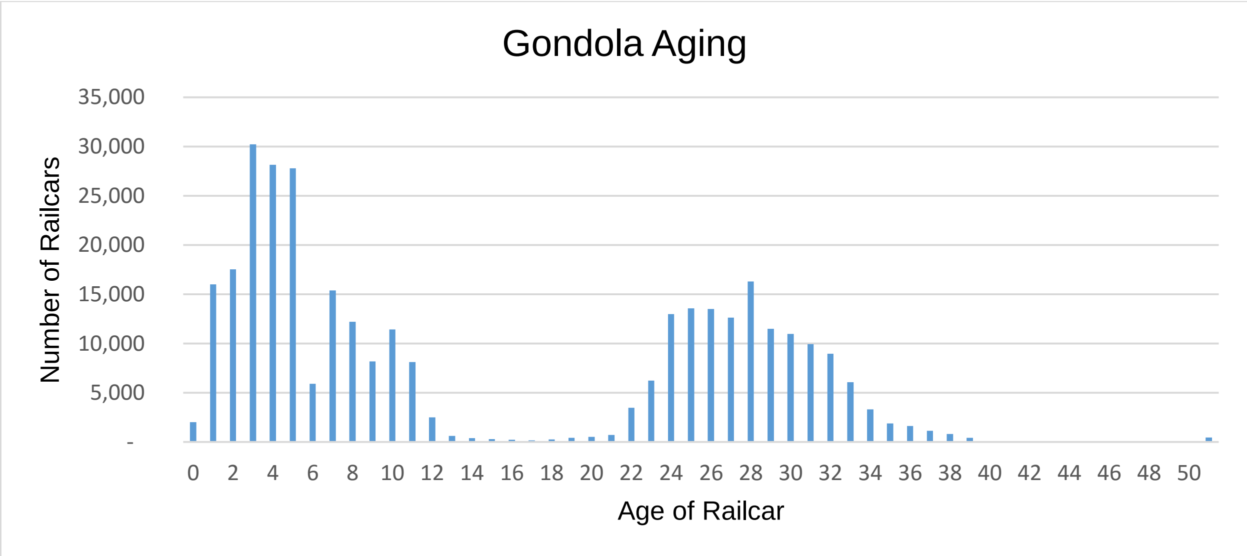


Figure 4: Number of Railcars Produced vs. Age of Railcars

Figure 5 shows a closer view of the railcars that need replacement. A vast majority, 91%, of the railcars in the group shown in Figure 5 belong in the 24 to 34 year age group, which directly relates to the last ten years of the Soviet Union.

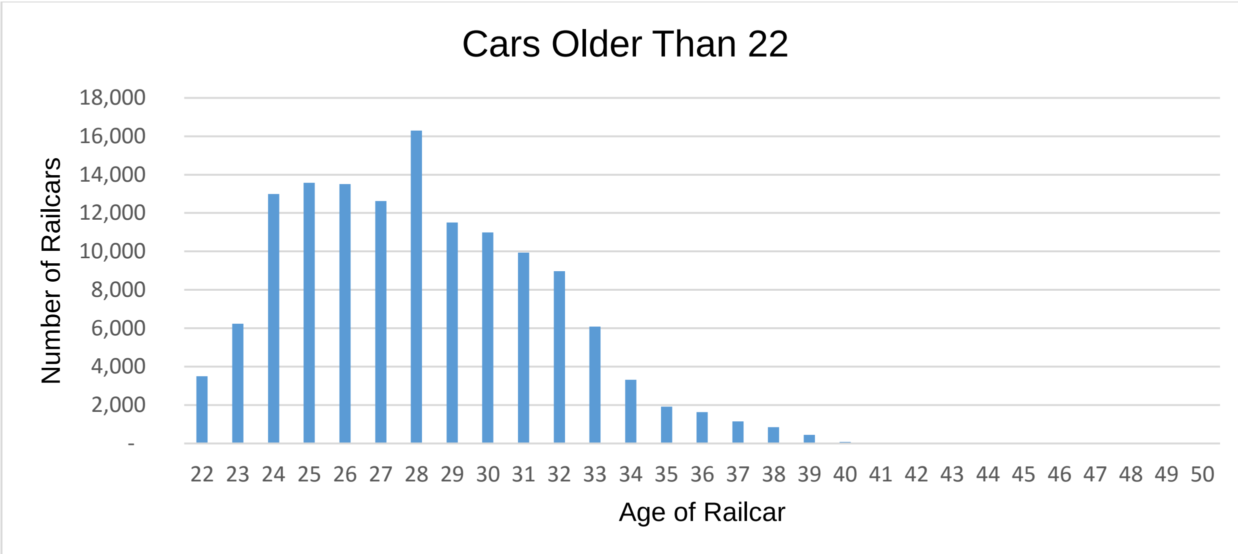


Figure 5: Number of Railcars Produced vs. Age of Railcars, (older cohort)

According to Aleksei Roev (personal communication, September 9th, 2015), Brunswick Rail Analyst, an important factor to look at is the average age of the railcars in use. This analysis helps with understanding the overall health of the system by multiplying the number of railcars and their respective ages and then dividing by the total number of railcars. The average age of all railcars in the system is 14.8 years (see Appendix H), which is quite close to the 22 year service life limit.

There are, however, conflicting results on exactly how many railcars need replacement. Using data obtained by Brunswick Rail in 2015, we created a histogram that shows the expected railcar write offs by 2020 by Russian Railways (see Figure 6). When these numbers are added together, RZD expects 109,438 railcars to be written off from 2015 to 2020. This expectation is a decrease of 26,194 railcars less than we had originally calculated (135,632) to need replacement. We are unsure what will happen with the remaining 26,194 railcars that are already at the age of replacement, but the fact that they will need replacement remains. Perhaps RZD plans to recertify them and put them back into operation, but for our purposes, they still need to be replaced.

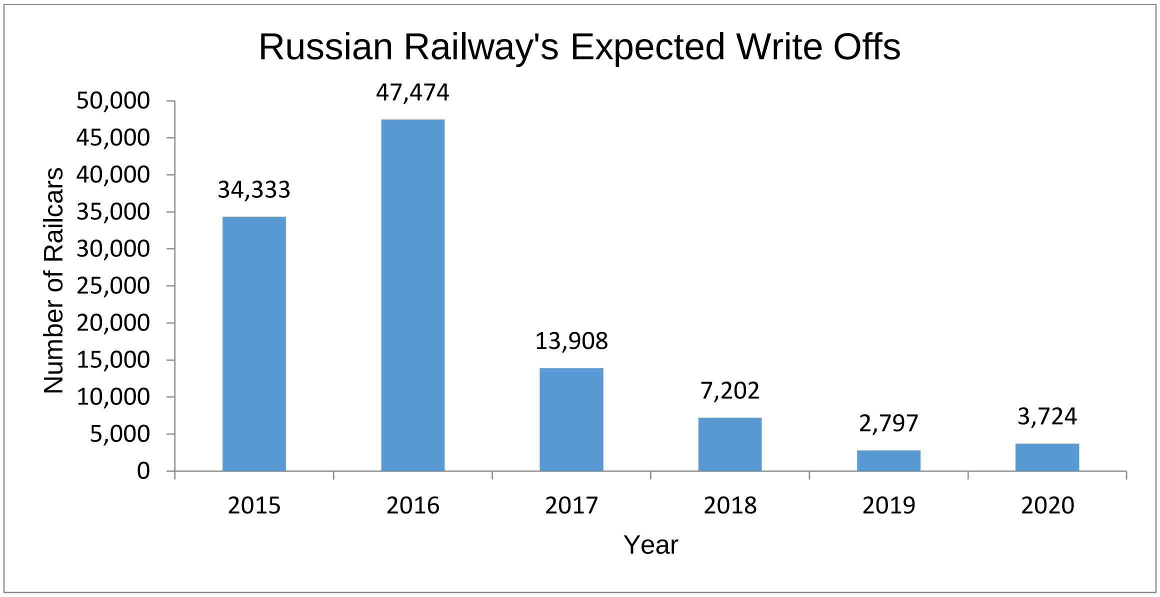


Figure 6: Russian Railway's Expected Write Offs

Russian Railway’s expected write offs by 2020 are in addition to the write offs from 2012 to September 2015, which can be seen in Figure 7. These numbers added together totals to 67,207 railcars. It is unclear how many of these 67,207 railcars need replacement.

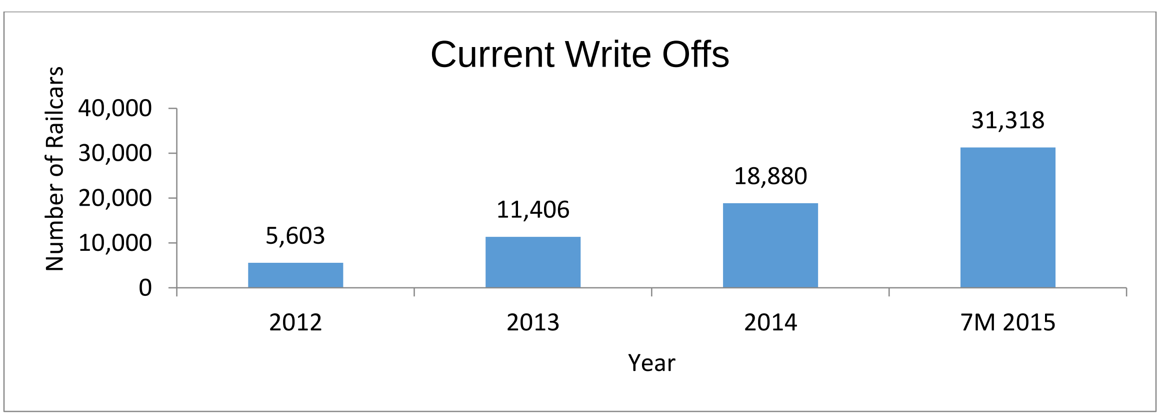


Figure 7: Current Write Offs

Also, by 2020 the average age of these railcars will have increased by 5 years, as shown in Figure 8. A further 2,165 railcars will have reached more than 22 years of service at the same point. We expect the age of railcars in the system to resemble a similar trend as Figure 8 in 2020. For the predicted five years, an average of the previous ten years (17,289 railcars) was computed and inserted into the graph. It is unclear if Russian Railways has included these 2,165 railcars in their total of 109,438 expected write offs.

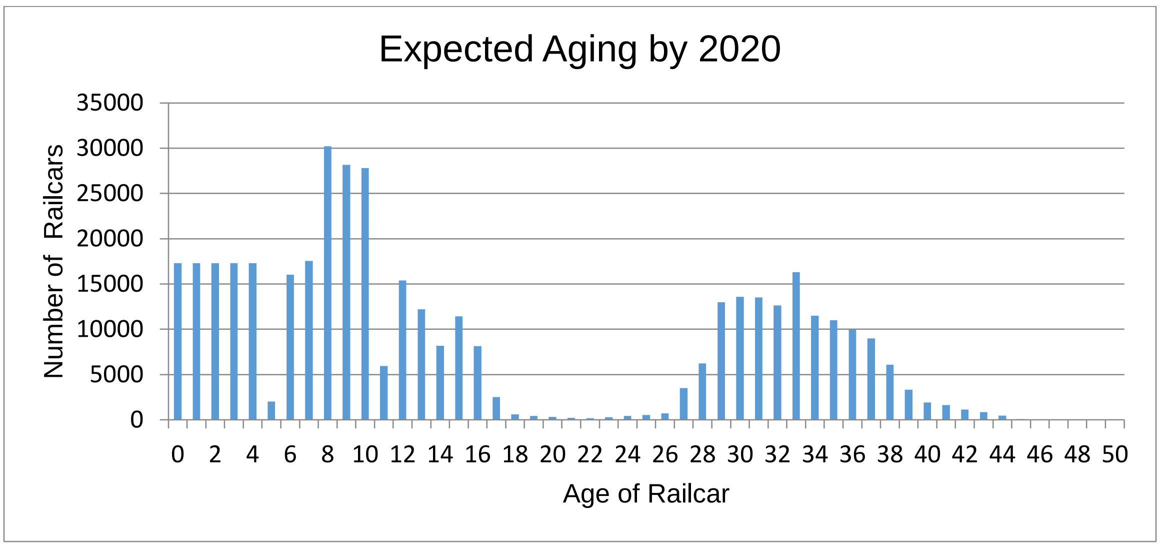


Figure 8: Number of Railcars Produced vs. Age of Railcars in 2020

From our calculations, by 2020 there are 137,797 (135,632 + 2,165) railcars that will need to be replaced. This is in comparison to the 109,438 railcars that RZD expects to be replaced by the same year. There is a difference of 28,359 that have not been written off and it is unclear if these will be granted service life extensions or will be replaced.

The exact number of railcars that will be written off depends on policy, which is discussed in Section 4.6. If the pace of write-offs increases, an acceleration in the reduction of the age of the system's railcars will occur. However, the more likely scenario is that service life extensions will continue to be granted, and the old railcars will stay in use. For the following sections, we assume that our original calculation of 135,632 railcars will be replaced.

4.4 Environmental Analysis

In this section, the economic and environmental impact of purchasing new generation railcars is assessed. Two factors were considered for analysis, including carbon dioxide emissions from the production of the previous generation railcar and from NGRs and the fuel consumption during use of each type of railcar.

4.4.1 Carbon Dioxide Emissions Analysis

The use of NGRs creates 29 percent lower CO2 emissions than continuing to use the old design over the next 65 years. Using the analysis presented in Section 4.3 we determined 135,632 railcars need replacement in the near future. These railcars can be replaced either with the old generation railcars or with NGRs. If the railcars are replaced with the old generation railcars, the functional life span will remain at 22 years. The railcars could also be replaced with NGRs with a service life of 32 years. Over the next 65 years, the old generation railcars will need to be replaced an average of three times. By comparison, if NGR railcars are used, each railcar will need replacement two times. Thus over the 65 year period, the old generation railcar will need replacement one and a half as many times as a NGR. Note that some railcars will need replacement before the service life is up, and depending on policy, railcars that have passed the service life could be retrofitted or granted an extension.

Gondolas are usually made out of steel. According to World Steel Association's (2011) life cycle analysis for every 1 kg of steel produced, an average 1.6 kg of CO2 is released into the atmosphere. The emissions data were collected in accordance to ISO 14040: 2006 and ISO 14044: 2006 standards with samples coming from 17 countries around the world. If the railcars are replaced with NGRs, such as the Tikhvin 12-9869, the resulting CO2 emissions would be 10,850,560,000 kg. If the old model 12-132 is continued to be produced and used from Uralvagonzavod, Ruzkhimmash, JSC Transport engineering, and Mogilev FAZ, the result would be 15,299,289,600 kg of CO2 emissions. Thus the utilization of NGRs would result in a 29 percent lower CO2 release. This calculation can be seen in Table 4.

Table 4: Carbon Dioxide Emissions in producing OGRs versus NGRs over 65 years

Model	Kg CO2 per Kg Steel	Kg of Railcar	CO2 per Railcar	Replacement in 65 Years	Railcars to be Replaced	Total kg CO2 Produced
NGR	1.6	25000	40000	2	135,632	10,850,560,000
OGR	1.6	23500	37600	3	135,632	15,299,289,600

4.4.2 Fuel Consumption

The use of NGRs versus the current design of railcars results in similar fuel usage characteristics. In order to determine the amount of fuel used by each type of railcar, a simulated comparison of transporting 10,000 kg of coal was used over a distance of 5,000km. The Tikhvin 12-9937 was selected to represent the NGR, while the 12-132 model used by Russian Railways was chosen to represent the old generation gondola. Unfortunately, we were unable to find publicly available fuel efficiency data for Russian Railway's locomotives. We had to make some assumptions according to an investigation by *Wired Magazine*'s Rhett Allain (2011). The frictional force presented by drag on the length of the train can be ignored, as most of the effects from drag will be on the locomotive and the very last railcar. Allain continues on to state that railcars have a very low frictional force on the track. Appendix F contains the data and results of the analysis. For the 10,000 kg of coal, NGRs provide a 0.25% reduction in fuel usage over the OGRs. In case the density of the material made an impact on the fuel usage, a similar simulation was completed using coarse sawdust. NGRs used 0.61% more fuel than OGRs at 678,768 liters versus 674,627 liters used. Both of these percentages are insignificant, indicating there is little impact on the environment based on fuel usage between NGRs and OGRs. This numbers can be shown in Appendix F.

An important finding is the break-even point for the fuel consumption. The density of the material decides how efficient the train is. When the density of the material being transported by the railcar matches the density of the railcar itself then the train will be able to operate at maximum efficiency. For a NGR such as the Tikhvin 12-9937, the optimal density is 815 m^3 /kg. An OGRs' optimal density is 789 m^3 /kg. Extra processing of goods to fit the density optimization would have diminishing returns as the best density for NGRs and OGRs are very close.

4.5 Financial Analysis

The purchase of railcars requires due diligence in understanding how the investment will affect an organization's financial bottom line. Any benefits from a purchase, both fiscal and non-fiscal, cannot be realized if it will result in financial loss.

Using internal data from Brunswick Rail, Sperbank's (2015) report on predicted leasing rates and publically available data from our information collection efforts on NGRs, we constructed a sample cost-benefit analysis with several scenarios.

Contracts for leasing of railcars are different for each leasing company and each company in turn may have several different contract styles on terms of lease time and the handling of service costs. Several scenarios are provided to show the different situations that the railcars can be leased by. The first scenario provides a simple outlook on purchasing a railcar with cash and having the client pay for all maintenance. The second looks at purchasing a railcar with cash and handling all of the maintenance obligations. The final scenario provides a complex look into purchasing a railcar with a loan, scraping old railcars, using tax shields, and depreciation shields.

4.5.1 Assumptions

The analysis assumes the purchase of a 2,100,000 Ruble Russia NGR and compares it to the purchase of a 1,500,000 Ruble old generation railcar. Another assumption made is for the rate that can be charged by a leasing company for each gondola. The rates used were obtained from Sperbank's (2015) leasing report for NGRs and from Brunswick Rail's current leasing rate. Since the rate for OGRs will most likely improve in the future, a 315 Rubles per day increase is included for a total rate of 715 Rubles per day. Sperbank predicts a range in future pricing for NGRs from 1200 Rubles per day for a lease that includes full service costs to 750-800 Rubles per day for a lease that puts the responsibility on the client. The rates will change over time, so we assume that that the rate will change in proportion to the costs. New technology developed in the future may push the rates for the railcars further down in order to compete effectively.

4.5.2 Cash Purchase with No Maintenance

According to Sperbank's (2015) report, the expected rate for NGRs that are leased with maintenance paid for by the customer is 600 Rubles per day. This results in a yearly return of about 219,000 Rubles. Using an initial assumed purchase price of 2,100,000 Rubles, the break-even time is about 10 years. For an OGR with the same contract, a rate of 375 Rubles per day can be expected with a total yearly income of 136,875 Rubles. The break-even time is 11 years for these railcars. The NGR after this period will have a remaining life of around 22 years, making a lifetime profit of 4,908,000 Rubles. The OGR will have a further 11 years of working service with a lifetime profit of 1,511,250 Rubles. Thus, NGRs are 225% more profitable than OGRs over their respective service lives.

Realistically, the rates will increase in the near future as the economy recovers. Sperbank (2015) predicts that NGRs will reach a rate of 800 Rubles per day and OGRs will reach around 715 Rubles per day sometime between 2016 and 2017. The break-even period at this rate is 7 years for NGRs and 5 and a half for OGRs. The total profit is higher for a NGR with a lifetime return of 7,244,000 Rubles resulting in a 71% higher return than OGRs at 4,241,450 Rubles. This information can be found in Table 5 and Table 6.

Table 5: CBA Cash No Maintenance Current Rates

September 2015	OGR		September 2015	NGR
Lease Rate Rubles	375		Lease Rate Rubles	600
Yearly Price Rubles	136,875	NGR Profit over OGR, lifespan	Yearly Price Rubles	219,000
Assumed Cost Rubles	1,500,000		Assumed Cost Rubles	2,100,000
Service Life Years	22		Service Life Years	32
Break Even (Years)	11		Break Even (Years)	10
Years Remaining	11		Years Remaining	22
Lifetime Profit	1,511,250	225%	Lifetime Profit	4,908,000

Table 6: CBA Cash No Maintenance 2016-2017

Future 2016-2017	OGR		Future 2016-2017	NGR
Lease Rate Rubles	715		Lease Rate Rubles	800
Yearly Price Rubles	260,975	NGR Profit over OGR, lifespan	Yearly Price Rubles	292,000
Assumed Cost Rubles	1,500,000		Assumed Cost Rubles	2,100,000
Service Life Years	22		Service Life Years	32
Break Even (Years)	5.7		Break Even (Years)	7.2
Years Remaining	16		Years Remaining	25
Lifetime Profit	4,241,450	71%	Lifetime Profit	7,244,000

This model of cash purchase with no maintenance is the most realistic for Brunswick Rail (2014f) as the company usually stipulates that the customer pay all servicing costs. In addition, the company secures loans and bonds from investment banks creating usable cash that can purchase railcars without a secondary loan. Although the payoff is higher for a NGR, the break-even time is longer. Securing investment for this long of a payoff can be difficult to obtain and typically, shorter break-even times are preferred for investors.

4.5.3 Maintenance

Maintenance fees create a more complicated picture for choosing a railcar. From data obtained from interviews, the visit to EXPO 1520 and from Brunswick Rail's internal database we tabulated all maintenance service requirements in Table 7.

Table 7: Characteristics of Railcars

	Service life, years	Years until First Depot Repair	Distance until first Depot Repair KM	Term up to capital repair, years	Wheelset replacement term, years	Current repair, times per year	Bearings replacement term, years
New generation railcar (NGR)	32	4	500,000	16	8	~0.5	8
Old generation railcar (OGR)	22	3	250,000	11	7	1	5

According to Brunswick Rail's Analyst Aleksei Roev, years until first depot repair is the number of years mandated by Russian Railways that a railcar can be used before it needs to be inspected and all problems found fixed. However, if the railcar travels a length longer than the certified distance, then it also needs to go to depot repair and inspection. In other words, which ever limit is reached first creates the requirement that a railcar is inspected and fixed. Capital repair is a major repair required at the halfway point of service life. The wheel set replacement is the exchange of wheels and axle on the bogie for a new or refurbished pair. Current repair includes all other small maintenance on the railcar and is needed at irregular intervals throughout the year. Note that the current repair characteristics for NGRs is unknown at the moment, but it is assumed to be half of the OGRs' rate of one repair each year. The maintenance characteristics were then divided to find how many times each railcar would need the respective servicing over the railcar's lifespan as seen in Table 8. The complete worksheet is provided in Appendix G.

Table 8: Number of Times per Year Maintenance is Completed

	# of depot repairs during service life	# of capital repairs during service life	# of wheelset replacements during service life	Number of Current Repairs over lifetime	# of bearings replacements during service life
New Generation Railcar (NGR)	8	1	16	11	3
Old Generation Railcar (OGR)	10	1	12	22	4

Brunswick Rail compiled the cost of maintenance for OGRs and has rough expectations for the maintenance of NGRs. The cost of each service was multiplied by the number of times that the service would be required as seen in Table 9. These fees are used in the financial analysis later in this section.

Table 9: Maintenance Costs During Service Life of NGR and OGR

Maintenance costs (RUR) during service life:	NGR	OGR
Depot repair	520,000	650,000
Capital repair	200,000	100,000
Wheelset replacement	1,248,000	660,000
Current Repair	220,000	330,000
Bearings replacement	1,176,000	160,000
Total	3,364,000	1,900,000

4.5.4 Cash Purchase with Maintenance

A contract can be formed by a leasing company that stipulate the maintenance costs, as presented in Table 9, are covered by the customer. The true cost of ownership then includes the cost of purchase and repairs. The total costs are presented in Table 10.

Table 10: Railcar Total Costs

	NGR	OGR
New gondola price, RUR	2,100,000	1,500,000
Lifetime Maintance	3,364,000	1,900,000
Total	5,464,000	3,400,000

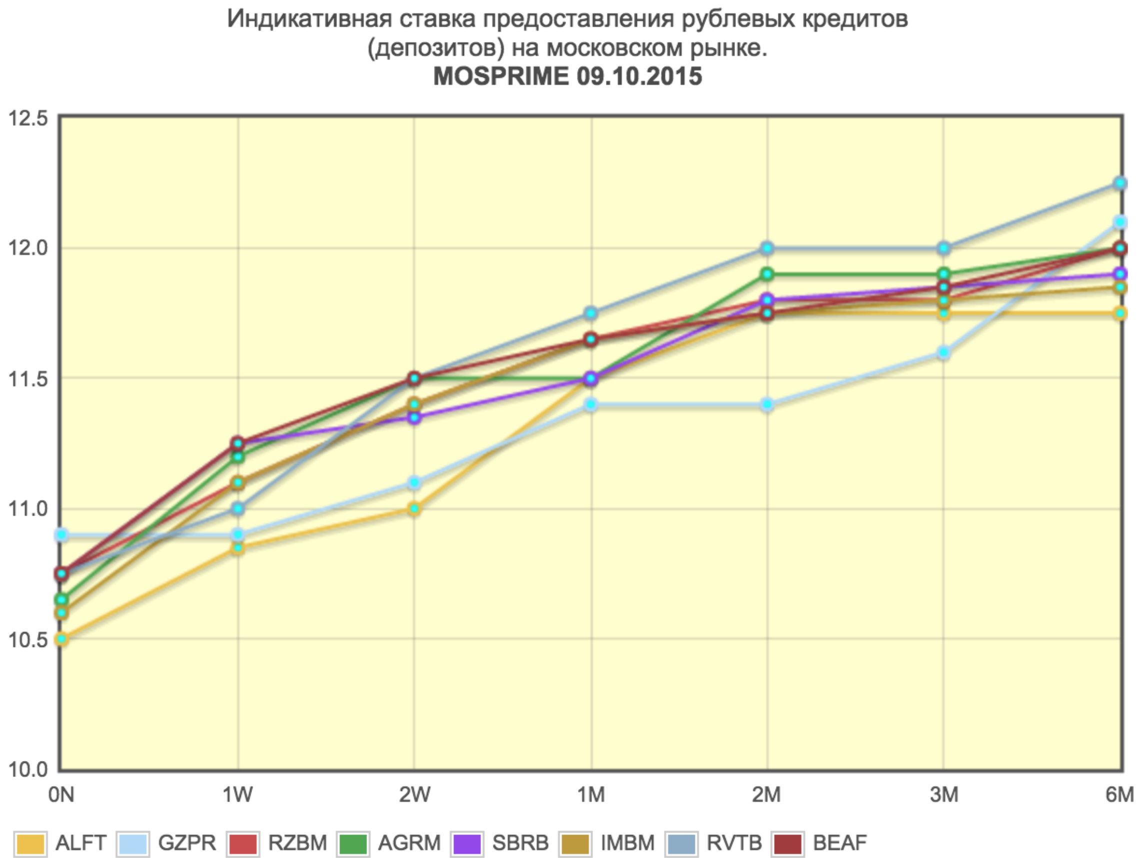
Sperbank justifies a rate of 1200 Rubles per day for a NGR contract that includes maintenance in 2016-2017. For a NGR the break-even time becomes about 19 and a half years with a net lifetime profit over the 32 years being 8,552,000 Rubles. For an OGR with the same contract at the daily justified rate of 940 Rubles, the break-even time is a little less than 10 years with a lifetime profit of 4,148,200. The lifetime service costs are just estimates for NGRs and the actual cost will not be known until NGRs currently in use begin to need maintenance. The break-even period for both railcars is longer than half of their service lives. For a NGR, the lifetime profit is about double that of a OGR but comes at the cost of breaking-even nine years later.

4.5.5 Financial Analysis with Repairs and Loans

The complete cost of ownership and real return rate needs to include several factors such as loans, depreciation and subsidies from the government. This section presents a selection of scenarios that could be used by Brunswick Rail or any other Russian leasing company.

Most purchasers of railcars will need to finance the upfront cost through a loan

(Mosprime, 2015). We assumed a 12% interbank interest rate as a base with a 3% addition for a total of 15% incurred interest over the lifetime of the railcar. The Mosprime interbank rate changes depending on the loan term but stabilizes after about 1 month at 12% as of October 2015. The history of the interest rate is presented in Figure 9. The loan period is assumed to be negotiated to end for the number of years until break-even.



Код банка	ON	1W	2W	1M	2M	3M	6M
MOSPRIME/ALFT	10,50 B	10,85 B	11,00 B	11,50 A	11,75 A	11,75 A	11,75 B
MOSPRIME/GZPR	10,90 T	10,90 A	11,10 A	11,40 B	11,40 B	11,60 B	12,10 A
MOSPRIME/RZBM	10,75 A	11,10 A	11,40 A	11,65 A	11,80 A	11,80 A	12,00 A
MOSPRIME/AGRM	10,65 A	11,20 A	11,50 T	11,50 A	11,90 A	11,90 A	12,00 A
MOSPRIME/SBRB	10,75 A	11,25 A	11,35 A	11,50 A	11,80 A	11,85 A	11,90 A
MOSPRIME/IMBM	10,60 A	11,10 A	11,40 A	11,65 A	11,75 A	11,80 A	11,85 A
MOSPRIME/RVTB	10,75 A	11,00 A	11,50 A	11,75 T	12,00 T	12,00 T	12,25 T
MOSPRIME/BEAF	10,75 A	11,25 T	11,50 A	11,65 A	11,75 A	11,85 A	12,00 A

Figure 9: Mosprime Interest Rates

According to Sperbank's (2015) report on NGRs, Russian law dictates that a subsidy is made available in the form of a 6% reduction on the interest paid on a NGR within the first year. This subsidy goes away in subsequent years.

Railcars are depreciating assets. For tax purposes, the depreciation each year can be counted against taxes owed as the asset is a loss and counts against income. The assumed value of the scrap for a NGR is 250,000 Rubles. The depreciation for each year was calculated by subtracting the scrap value by the initial cost, all divided over the life of the railcar.

The final return rate per day depends largely on the percent of financing needed. After the first year, the interest rate subsidy expires, so the second year results are different. A sample scenario is presented in Table 11. The scenario assumes that a load covers 25% of the initial cost and that an old generation railcar is scraped. All figures are in Rubles.

Table 11: 25% Financing with Scrap

Category (in Rubles/Year)	First Year	Years After	After Breakdown
New Gondola Price	2,100,000	2,100,000	2,100,000
Scrap Value	130,000	130,000	-
Financing %	25%	25%	0%
Price for Interest	492,500	492,500	-
Loan Interest Rate (Mosprime 3M + 3%)	15%	15%	0%
State Subsidy	6%	0%	0%
Net Rate	9%	15%	0%
Yearly Interest	44,128	73,678	-
Tax shield, Interest	8,826	14,736	-
Interest Actual	35,302	58,942	-
Depreciation	57,813	57,813	57,813
Depreciation Shield	11,563	11,563	11,563
Maintenance Average per Year	105,125	105,125	105,125
Total Costs per Year	128,865	152,505	93,563
Daily Rate	800	800	800
Total Income per Year	292,000	292,000	292,000
Net First Year	163,135	139,495	198,438
Break Even	*14*		
Years Remaining	*18*		
Total Profit	*3,581,223*		

A summary of each scenarios analyzed is presented in Table 12. All rates of return are above 10 years. Financing at or above 75% irrelevant of scrapping an older railcar is not an option as either the yearly return is negative or the time to break-even is more than 32 years. The rest of the scenarios are included in Appendix I.

Table 12: Complex Cost-Benefit Analysis Senarios

Scenario	% Financing	Scrap	First Year	Loan Period	Break-even	Total Return
1	0	yes	198438	198438	10	4380000
2	25	yes	163135	139495	14	3581223.086
3	50	yes	127833	80553	24	1613476.581
4	75	yes	92530	21610	88	-
5	100	yes	57228	-37332	-	-
6	0	no	198437.5	198437.5	11	4250000
7	25	no	160806	139495	15	3392978.804
8	50	no	123174	80553	26	1281750.457
9	75	no	85542	21610	94	-
10	100	no	47910	-37332	-	-

4.6 Policy Affects Development

Several of our interviewees highlighted how Russian Railways can affect railcar leasing and any decision to purchase NGRs or continue with the current generation railcars. While all interviewees mentioned policy during their respective interviews, the only common statement was about the ease of maintenance policies. Currently, bogies must be completely disassembled every three years and this process can take more than a week to complete (see Appendix D). With the new, innovative bogie design, this process is unnecessary as, according to Marcus Montenecourt, these bogies will last the railcar's entire service life. Because of these strict maintenance standards, every interviewee expressed this as a major reason that the implementation of innovations in railcar technology have been slow in Russia.

Though all interviewees mentioned policy, John Winner (see Appendix C) discussed why Russia's railways are behind other parts of the world and how policy can change to improve Russia's rail industry. He said Russia is behind because of strict maintenance policies that require the bogie to be rebuilt every three years, whereas in

North America railcars will travel 2.5 million miles regularly before the bogie needs to be rebuilt. Because of this Russian policy, no manufacturing company wants to build a bogie that lasts longer than three years. The government needs to allow for more flexibility in maintenance standards and even altering the maintenance process to a detailed inspection of the bogie every two years would save the rail industry time and money.

Winner also discussed many ways in which the Russian government can implement policy to improve the rail industry. The most dramatic way policy can affect NGRs specifically is to allow for changes in the tariff discount to allow for both RZD and the consumer to share benefits. There are only two NGRs that have a tariff and if RZD wants innovation in the rail industry, there must be more models that receive the discount.

In order to advance railcar technology further in the future, RZD needs to invest in rebuilding the main rail lines to create segments of track that can withstand loads of 27 to 30 tonnes per axle. Only mainlines can withstand 25 tonnes per axle, but many secondary lines cannot. Since 25 tonnes per axle is low compared to other railways in the world, RZD needs to begin replacing the current track. Also, if RZD was to invest in more advanced loading and unloading devices, a railcar could transport goods more frequently and be more profitable. This would be good for the economy and the rail industry in general.

The service life of railcars has been determined by RZD as 22 years for an OGR and 32 years for a NGR. In most cases, the railcars usable life will surpass these numbers. For RZD, a railcar that has reached the end of its service life needs to be recertified, and this process is expensive and can take too much time. In order for the rail industry to be more efficient, this recertification process could be shortened or removed.

A summary of the areas the interviewees expressed in common are presented in Table 13.

Table 13: Policies Affecting Railcar Purchasing Decisions

Policy	Result
Subsidies	Incentives create economic push for investments that benefit society
Flexibility in Standards / Certification	New technologies may need new regulations.
Regulate as needed	Under and over regulation of the industry can lead to systemic issues

4.7 Basic Leasing Business Model Structures

According to John Winner, there are four main types of leasing business models: classic, financing company, government operated, and equipment financing.

The classic leasing business model is an independent company that owns its own railcar fleet, is a stand-alone company, and receives funding from many private investors. An example of the classic leasing company is Brunswick Rail.

A financial leasing company typically leases railcars in addition to many other services. These companies can be owned by banks or, like General Electric, do research in the railcar industry and lease railcars for a small profit. Financing companies like investing in railcar leasing because it is constantly a profitable market.

Government operated leasing companies, for example railcar leasing in Canada, operate more as a public service. These companies buy specialized railcars to accommodate the demand within their country. This can be risky because if a large amount of capital is invested in grain railcars, for example, during the off-season these railcars will be unprofitable. However, in most cases, losing a small amount of money is not detrimental to these companies.

Finally, an equipment financing company sells equipment leases. These can be compared to a long-term mortgage or a bond. In other words, this results in a long-term lease agreement at a fixed rate. Many of these equipment leases are lease-to-own and exist in the United States. These companies try to maximize the depreciation on the railcars and are the principle financiers of the leasing business.

These are, of course, not the only types of leasing business models. There are unique structures such as TTX, a railcar leasing company that is owned by many railcar owners in the United States. TTX owns its equipment but does not lease one railcar to only one company. This means that a railcar that needs to transport goods for a mining company from Texas to Maine can then be used to transport goods from Maine to another part of the country instead of returning to the mining company in Texas empty. This operation is called railcar pooling and is unique to the United States.

4.8 Summary

Both NGRs and OGRs have different characteristics that change their mechanical advantages, impact on the environment and financial implications. Several important conclusions will be drawn in the next chapter using this analysis.

Chapter 5: Conclusions & Recommendations

From our previous analysis, we present conclusions and recommendations to Brunswick Rail on the adoption and use of New Generation Railcars. These recommendations can be applied to other railcar leasing companies and the industry as a whole where appropriate.

5.1 Conclusions

Based on our research we conclude that bogie design, volume, carrying capacity and service life are the key factors in defining innovation within Russia's up and coming railcar fleet.

Increased capacity allows fewer railcars to be used and allows the system to be more efficient. Formally, the larger capacity by weight (about 8.9%) and by volume (about 4.5%) allow for a reduction of similar numbers for each in terms of railcars used. This leads to less congestion in the system and less wear on the tracks. From our data comparison and analysis of the key factors, **we define a NGR to be an increase of 5 to 6 tonnes in carrying capacity by weight, at least a 4 m^3 increase in capacity by volume, and a 10 year increase in service life.**

The longer service life of NGRs makes them a financially appealing option. The initial cost and higher service costs over the life of a railcar are important to consider, but they are offset by the increased lifespan and higher rate that can be charged for the increased carrying capacity. The 10-year service life extension is a 45% increase on the usable life of the railcar.

Subsidies play a large role in purchasing new railcars. Care should be taken to fully understand the policy climate around incentives. Policy makers have several options at their disposal to push the market in one direction or the other.

The operation of NGRs does not result in a significant reduction in fuel usage, with both of our simulations resulting in less than 1% reduction in fuel used. If the density of the material is less than 789.7 kg*km/m^3, then the old generation railcar may be better. However, significant reductions in carbon dioxide released during the production of steel for the railcars (29%) can be achieved through the longer life of a NGR. The extended life makes NGRs the better option in terms of the environment.

At the current moment, Brunswick Rail is leasing OGRs at or below the cost to maintain them. Fortunately, the daily leasing rates are predicted to rise from the current low to a sustainable and profitable rate.

From trends discovered in other areas, heavy haul lines up to 44 tonnes can be used in the future. As Russia's economy changes over time, the need for heavy haul may become apparent.

5.2 Recommendations for Brunswick Rail

We recommend NGRs should not be purchased at the current time. The current rates for leasing need to stabilize at the predicted 750-800 ruble mark before purchase becomes a viable option. With that realized rate, NGRs are the socially, environmentally and financially sound choice. If Brunswick Rail decides to purchase new generation railcars, they should be purchased with cash from investors. Financing at or above 75% should not be used because the rate of return is negative. From our analysis, all financing options have a smaller rate of return than a purchase with cash. Existing loans or money raised from investors should be used to avoid paying interest to both a loan agency and dividends to investors.

We recommend further research into NGR maintenance costs in order to complete a full cost-benefit analysis. NGR maintenance costs are currently only estimates. The full price will be unknown until the NGRs produced in 2012 begin to need maintenance, after this, real costs can be used. In our analysis, several factors were assumed or taken as constant, for example the exchange rate. Also, the conditions presented will not stay constant for the entirety of a NGR's service life and are therefore difficult to predict.

We recommend Brunswick Rail place the cost of maintenance on the customer. Maintenance costs, especially for NGRs, are a large portion of costs and and are volatile in nature. Brunswick Rail will avoid risk by having the customer pay for all maintenance. If Brunswick Rail is to pay for maintenance, we recommend waiting to purchase NGRs until the price has reach 1200 Rubles per day and OGRs until the rate reaches 715 Rubles per day.

We recommend further research into Australia's rail industry and its government policies to determine possible better railcar leasing practices and general improvements. Australia's rail industry is similar to Russia's in that it is owned by the government, goods need to travel long distances and are often traveling to the opposite side of the country. Since Australia is currently using the most advanced technology in the world, and its rail industry is extremely profitable, it would be beneficial for Brunswick Rail to analyze this country's specific policies, technologies and financial arrangements more carefully.

5.3 Summary

The next generation railcar is an exciting development that begins the trend for innovation in Russia’s rail industry. They are a step forward in modernizing the system that is responsible for the transport of a majority of goods in Russia. New generation railcars provide benefits to leasing companies, customers, and Russian Railways through improved mechanical characteristics. However, these benefits come at significant financial cost. When the daily rates return to normal, leasing companies and railcar owners in Russia can begin the replacement of their aging railcars.

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Appendix A: Sponsor Description

Brunswick Rail’s (2014c) six members on the Board of Directors meet at least 4 times per year in person and discuss the development of the business. Under these Board members there are committees: the Strategy committee, Credit committee, Audit committee, Governance and Positions committee, and Compensation committee. These committees execute the Board’s decisions and handle the overall operations of the business. Under these committees are the general employees who execute these tasks. For our project we worked with the Strategy committee which “has responsibility for developing and refreshing our vision and strategy and overseeing its implementation” (¶12).

Brunswick Rail’s (2014c) structure mandates several committees that are responsible for overall governance. Financial information regarding accounts and shareholder relations are handled by the Audit Committee. The Credit committee takes care of business contracts with other companies. Figure 10 presents the organization’s structure in visual form. Brunswick Rail’s senior management consists of highly qualified executives (Brunswick Rail, 2014c). Most have master of business administration degrees from respected universities such as Harvard Business School and Sloan School of Management combined with several years of experience. Brunswick Rail (2014e) also maintains a commitment to more than just the business. The company provides scholarships for students studying rail transportation and several members do community service through the Volunteer Club.

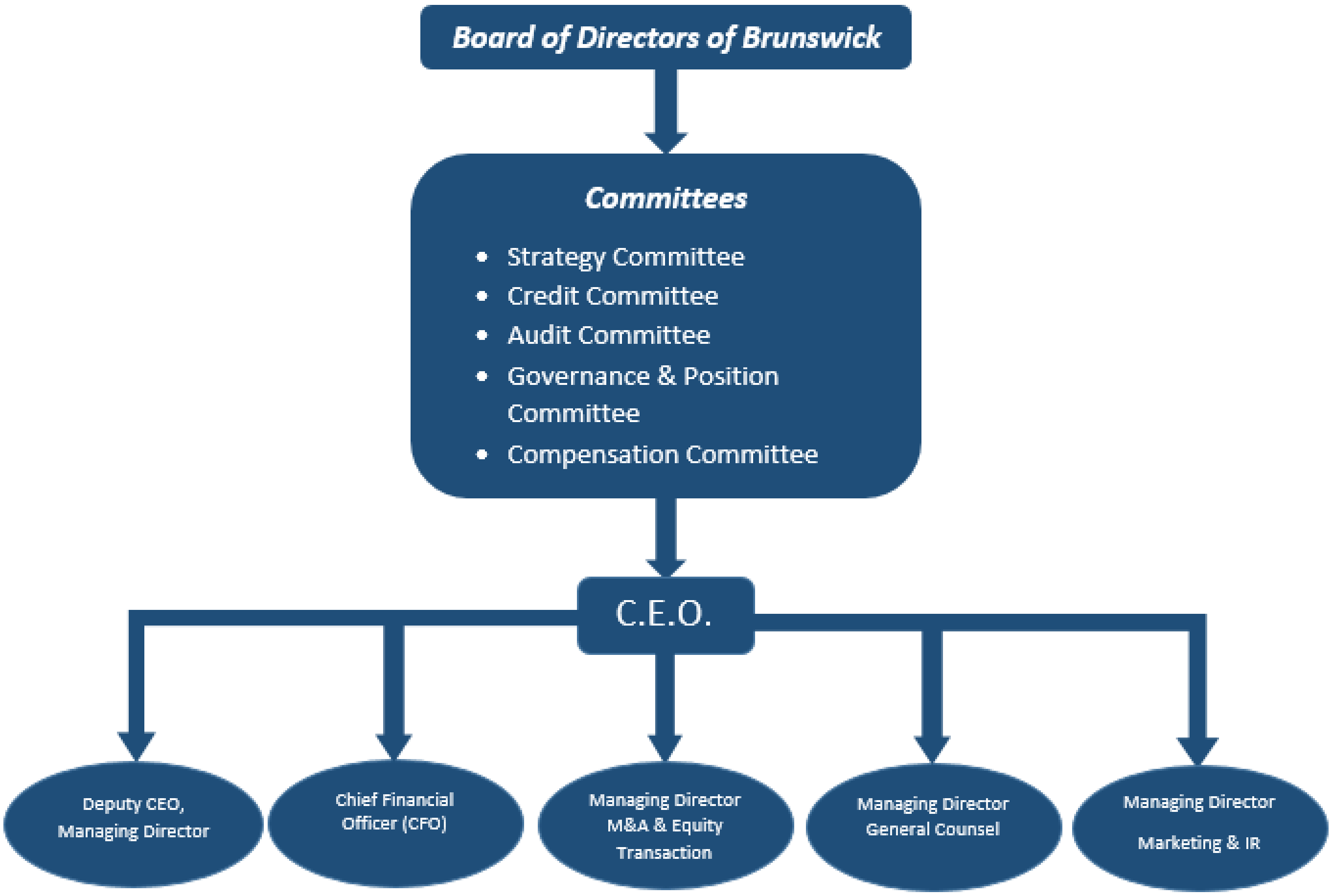

Figure 10: Company Structure of Brunswick Rail

Appendix B: Interview Summary for Lilia Lavrova

We were introduced to Ms. Lavrova via Brunswick Rail's Richard Sultanov while collecting mechanical parameters of the various NGRs being exhibited at EXPO 1520. The team, advisors, and representatives of Brunswick Rail joined her and other managers of the United Wagon Company. We discussed maintenance advantages of NGRs and the benefits and features of the NGRs produced by UWC's Tikhvin manufacturing plant. Some of the questions asked were:

- How long have you been working for United Wagon Company?
    - What was your previous place of employment?
- Does UWC work all over Europe?
    - Are there plans to expand the company?
- How do you switch from manufacturing old generation railcars to new generation railcars?

We thanked Ms. Lavrova for her time and asked for a follow up email interview.

Appendix C: Interview with John Winner

Interview Protocol

We first introduced ourselves and explained that we are students completing a research project for Brunswick Rail. We then explained our project goal of constructing a comparative analysis of New Generation Railcars and how they compare to new railcar technology trends around the world. Before our phone interview, we had asked if we could record our conversation, but Mr. Winner was asked this question again at the beginning of the phone call to make sure he still agreed to this. He was then asked if we can quote him in our report or if he would like to remain anonymous.

1. How do Russia NGRs compare to the new technologies in the rest of the world?
2. Innovation in the railcar industry has taken many forms. What is your idea of a New Generation Railcar in Russia (China, India, United States, and European Union)?
3. What are some new railcar technology trends in the world that could be relevant for use in the Russian context?
4. Can you describe the business model generally used in these parts of the world?
    1. Russia
    2. China
    3. India
    4. United States
    5. European Union
5. How do you see policy of the Russian Government influencing the deployment of NGRs (e.g. prices, tariffs, service life extensions)?

6. We may have more questions later. Could we please contact you later with additional questions?

We then thanked Mr. Winner for his time and sent him a follow up email thanking him again.

Interview Summary

After explaining our project objectives to Mr. Winner, we asked the first question. Winner expressed in his opinion that Russia is 10 years behind North America and 10 years ahead of Europe. The factors considered in this statement are axle load, tare weight, volume and space, speed of movement and speed of loading, rail wear, and service life. Depending on the strengths and weaknesses of these factors determines the level of the railcar technology advancement of a country. These factors must also be considered when defining a new generation railcar.

For question two, Winner defines a new generation railcar not only from the above factors, but by the bogie design. According to him bogie improvements are one of the most expensive major investments a manufacturer can make in terms of railcar improvements. Many experiments are needed to properly test a bogie’s strengths to determine when the steel casting will break. Though expensive, Winner said this is the defining factor of a NGR.

Next, Winner informed us that Russia signed an agreement with Brazil to build a high speed railway. With mostly transporting mass amounts of grain and soybeans, their railway only needs to be built to handle a load of 20-25 tonnes per axle. Currently, Valley Railways, the leading railcar operator company, transports 130-140 tonnes a year.

To question three, Winner described railcar technologies from North America, Europe, South America, and Australia. In North America, higher axle loads are achieved because of the shape and taper of the roller bearings, the rollers are more robust, the design and metallurgy are advanced, elastomer side bearings are used to reduce forces on the bogie, the bogies are made of steel, and there are spring loaded side bearings in wedges and the wheels. The bogies are relatively similar to the ones currently being produced in Russia, but in North America most of the work has gone into timing weight and they are manufactured with a much higher precision than the rest of the world.

Winner then expressed the reason why Europe is 10 years behind Russia is because Europe does not rely on rail freight transportation and does not care about advancing their current railcar technology. This development has been pushed aside in favor of other transportation methods. Europe's railways have a low axle load and their railcars are using an ancient bogie design.

On the other hand, South America is closely on par with the United States and primarily transports iron and coal on a heavy haul rail line through the amazon. However, the rest of the system is not as advanced and is similar to Europe and is not profitable.

On the other side of the world, Mr. Winner expressed excitement for the most advanced railway in the world in Australia. Railcars and bogie castings are locally produced and can withstand a load of 40 to 45 tonnes per axle. Government policy in Australia is supporting higher speeds so that the capacity on the current railway system can be increased. Winner said Australia believes "the higher the speed, the further you can get in one day" and are mostly interested in optimizing their entire system.

To question four, instead of describing the leasing business models from each country, Winner described the four general models of railcar leasing businesses, classic lease, financial lease, government lease, and odd lease. The classic leasing business model, for example Brunswick Rail, owns a railcar fleet, is an independent organization, and receives funding from many investors. The financial leasing company, for example GE Capital or a bank, leases railcars as a secondary business because railcar leasing is consistently profitable and the company receives the depreciation on the railcars. A government leasing company, for example Canada, is used in cyclic markets that have major public interests like grain. Government leasing companies will buy specific railcars, like for grain, but this can be a risk because the railcars will not be operated during the off season. Finally, odd leasing companies, for example the United States pooling company TTX, have leasing structures unique to their company.

Lastly, Mr. Winner, in response to question five, discussed why Russia is behind and how policy can change to get Russia ahead. Russia is behind because of strict maintenance policies that require the bogie to be rebuilt every two to three years whereas in North America, railcars will travel 2.5 million miles regularly before the bogie needs to be rebuilt. Because of this policy, no manufacturing company wants to build a bogie that lasts longer than three years.

There are many ways Russia in which the Russian government can implement policy to improve the rail industry. The most dramatic way policy can affect NGRs specifically is to allow for changes in the tariff discount to allow for both RZD and the consumer to share benefits. The government also needs to allow for more flexibility in maintenance standards and not require the complete teardown and reassembly of bogies before recertification. Even altering the maintenance process to a detailed inspection of the bogie every two years would save the rail industry time and money.

In order to advance railcar technology further in the future, RZD needs to invest in rebuilding the main rail lines to create segments of track that can withstand loads of 27 to 30 tonnes per axle. Also if RZD was to invest in more advanced loading and unloading devices, a railcar could transport goods more frequently and be more profitable. This would be good for the economy and the rail industry in general.

In summary, if RZD raised technical standards, adjusted the maintenance process, subsidized more of a new generation railcar cost, and ordered the industry to scrap old wagons, Russia would be able to advance to higher standards.

Appendix D: Interview with Marcus Montenecourt

Interview Protocol

We first introduced ourselves and explained that we are students completing a research project for Brunswick Rail. We then explained our project goal of constructing a comparative analysis of New Generation Railcars and how they compare to new railcar technology trends around the world. Before the interview, we have asked if we could record our conversation and then Marcus Montenecourt was asked again at the beginning of the conversation. He was then asked if we can quote him in our report or if he would like to remain anonymous.

1. Innovation in the railcar industry has taken many forms. What is your idea of a New Generation Railcar?
2. What is the typical railcar leasing business structure in the United States?
    a. What kinds of services do they offer?
3. Since your company works globally, how do you think Russia’s railways compare to others?
4. What are some railcar trends in the world that could be relevant for use in the Russian context?
5. We will have more questions later. Could we please contact you later with additional questions? If so, please provide us with your contact information.

We then thanked Marcus Montenecourt for his time and sent him a follow up email thanking him again.

Interview Summary

Marcus Montenecourt began the interview by explaining the history of Amsted Rail and their involvement in Russia. Amsted Rail is a 100 year old American company founded on steel companies making products for railways. Globally, it is a 4 billion dollar company, half of which is invested in the railroad industry.

Currently, Amsted Rail is a manufacturer of railway equipment for all pieces under and on either side of the railcar. They are the largest railcar wheel producer in the world, producing more than 1.3 million a year. The supplier for all of Amsted's steel products is Metal Invest Eskol Steel. Russian producers cannot manufacture perfect steel, so Amsted has to look to other countries. Amsted Rail also manufactures all components for railcars in Brazil. Manufactured and sold in Russia: bearings, side bearings, springs for bogies, articulated wagon, gears, and eventually couplings.

Amsted Rail is also the creator of the motion control bogie that they cast and produce themselves. It weighs 5-6 tonnes and they have licensed out this bogie to manufacturers in Russia. Tihkvin is using full motion control design and will be producing it in 2017 and will test the first batch in Turkey. There are three companies that want to be in the bogie manufacturing business; the two Russian ones are South Ural Railway (a subsidy of Russian Railways) and UWC. The companies using the motion control bogie are Altaivagon, Promtractor Wagon, MKZ, Roslova, and Eurowagon.

Europe, unfortunately, cannot use this bogie because of the European standards are different. They use a bogie called Y25 which cannot handle high load and it costs twice as much to manufacture.

Every section of the world has different standards that the rail industry needs to uphold. CIS has its own standards, Europe has different standards, and the US and many other parts of the world have AAR. For example, the rail gauge is different in Russia because during the cold war, Stalin didn't want Germany using their rail system to invade Russia so when constructing the railroad he made sure it would be impossible.

Amsted Rail partnered with EPK (European Bearing Corporation) to produce, assemble, and distribute new, innovative bearings together. Amsted partnered with EPK because they had 80% of the market share of bearings in Russia. They were manufacturing the cylindrical bearing and now produce the new cassette bearings. The current cylindrical bearing cannot handle heavy loads, but new cassette bearing can better handle heavy side loads (for turning) and vertical loads. These bearings do not reduce hunting, or the violent chatter between the railcar wheels and the rails, but instead it keeps the wheels locked in place on the bogie.

In the bad economy, the best way for Amsted to make money is to export these new bearings all over the world, but mostly to North America. Amsted Rail's most modern bearing manufacturing plant is here in Russia. They manufactured 20 million bearings and sent them all to North America. Today, 80 to 90 million dollars are directly invested into the new bearing plant in Russia. The first year that the bearings were manufactured 30,000 bearings were made, in 2014 100,000 bearings made, then there was a crash because of politics and in 2015 only 50,000 bearings have been produced. Montenecourt predicts that 2016 will be back up to 100,000 bearings. This July, they started exporting 10,000 bearings a month to the US. Mr. Montenecourt expressed the company plans to export the side bearing around the world.

The bearing that is being exported to the United States is called a K class bearing, which is the new bearing being produced in Russia, but it is scaled in inches instead of metric. This bearing has been AAR approved and it can supply any AAR market like India and Australia.

Cassette bearing benefits: more reliable and doesn't need service, bearing rollers are pitched which allows for heavier loads and it distributes weight better because of the different diameters in roller height, it doesn't need to be rebuilt every 50km, can handle side loads during terns better, handles higher speeds, when it reaches the end of its life it can be rebuilt and reused..

Montenecourt described the Russian rail industry as a cyclical industry. When there are a lot of companies buying railcars at one time, a backlog is created because manufacturer doesn't have enough railcars made. However when the manufacturer has caught up with the backlog, companies stop buying railcars and there's a lull in demand. Then it all repeats. Montenecourt says the manufacturers need to have a better ramp up and then down scale when needed.

The overall supply and demand of railcars is an interesting market; "lobby of railcar producers vs lobby of owners". The railcar producers want railcars to be obsolete so companies will purchase new railcars, but railcar owners want their railcars to last a long time so they don't have to purchase new ones.

Some of Montenecourt's general business advice:

-"you have to be a low cost producer in this market"

-Company decided to localize in the declining economy

-Amsted decided to work with the competition as a supplier and sold them motion control bogie design

-“government can exclude any company” <- should play nice with competitors because - Russian government can hurt whoever they want to

-“you have to have multiple technologies as a company, not just one”

-“In a bad economy, a company must mobilize all of its support”

-Amsted “wants its story told” and invests alongside Russian partners, doesn’t exclude any company as a customer/partner -> “every railcar producer is a customer”

-In a crisis companies have to learn how to “re-engineer their business”

After the detailed introduction to Amsted Rail and the Russian rail industry, we asked Mr. Montenecourt our interview questions. According to Mr. Montenecourt, a new generation railcar has characteristics including increased capacity, improved infrastructure, and less frequent maintenance. Because of the improved infrastructure, in this case the use of the motion control bogie, a railcar can operate at a lower cost, run at increased speeds and more efficiency, and run with better safety. Mr. Montenecourt discussed the unfortunate issue of required depot and capital maintenance performed every two and ten years respectively. Even though this innovative bogie does not need frequent maintenance, by law it is required. He described this as unfortunate because an improved bogie version will never save a company money or time in regards to maintenance.

Next, question two was asked and the railcar leasing business structure of the United States was discussed. Mr. Montenecourt said that in the United States, the railcar manufacturer makes the leasing businesses and shale gas drives the rail industry. The leasing business also doesn't provide expediting, or taxi services, like in Russia. This service is offered only by the railcar operators. An example of the typical American railcar leasing company is CIT, formally GE.

Mr. Montenecourt expressed his opinion that Russia's railways are dated. The three major rail markets are the United States, China, and Russia, yet Russia is at least 10 years behind both of these countries. Russia has been using the same bogie design since the 1950s and finally within the past decade new technology and massive changes have been implemented.

The most relevant new technology trend in the world for the Russian context is heavy haul. Mr. Montenecourt said that it is important to always push the limit of the current railway infrastructure. Right now the rail infrastructure can handle 23.5 tonnes per axle and there are measures currently being taken to change this to 25 tonnes per axle. Though this is an important change for the Russian rail industry, in the United States, there are railcars that can handle 32.5 tonnes per axle and in Australia where 45 tonnes per axle are being tested today. Montenecourt said in order for the railcars to carry more weight, they must have a higher axle load, the operating costs must be lowered, and the power must be distributed.

Appendix E: Interview with Pavel Ivankin

Interview Protocol

We first introduced ourselves and explained that we are students completing a research project for Brunswick Rail. We then explained our project goal of constructing a comparative analysis of New Generation Railcars and how they compare to new railcar technology trends around the world. Mr. Ivankin did not speak English, so one of the Russian students translated for us:

1. Innovation in the railcar industry has taken many forms. What is your idea of a New Generation Railcar?
2. How do you see NGRs improving the rail industry?
3. What improvements would you like to see within NGRs?
4. How would you weight the following parameters for evaluating a railcar? Increased volume, increased weight capacity, less maintenance and increased efficiency?
5. With the new RZD President, how do you think the discount on NGRs will change?
    a. How will this affect the current NGRs?
    b. Can you explain the general sentiment towards NGRs expected from RZD?
6. Who pays the tariff on NGRs, Brunswick Rail or the lessor?
7. Could we please contact you with additional questions later?

We then thanked Pavel Ivankin for his time, and one of the Russian students sent him a follow up email thanking him again in Russian.

Interview Summary

Pavel Ivankin began by explaining the two categories that he believes defines a NGR, infrastructure and commercial. The infrastructure, meaning the bogie, increased its standard from 23.5 tonnes per axle to 25 tonnes per axle. The commercial category refers to the railcars increased body volume, dimensions, and payload capacity.

To question two, instead of describing the improvements that NGRs make to the rail industry, Mr. Ivankin described the limitations. He said that NGRs are limited by their infrastructure because only the well-traveled, main lines can handle 25 tonnes per axle. Most of the secondary lines would break under the higher load and many private owners do not want to invest in NGRs because of this.

Maintenance centers are also an issue because they must be specialized and equipped to repair these new railcars. There are enough along the mainline, however if a NGR travels along a network that is not usually used and needs to be repaired, the repair center closest to it would not have the correct parts.

SUEK, the largest coal company in Russia, uses NGRs and saves 36% of transport fees for every railcar shipped. Mr. Ivankin said on the surface this seems great, but SUEK invested a substantial amount of money into the reconstruction of their private rail lines in order to put NGRs into circuit. SUEK also constructed new ports, loading systems, and tunnels that can support NGRs. This investment will keep SUEK in the negative for many years to come.

Ivankin feels that this is less efficient than the United States. It took NGRs seven years to get certified in Russia, a process that would have taken three years in the United States. Ivankin said there is a lot more freedom and room for innovation in the US. Also, the cost for certification is expensive and Russia and it is difficult to make adjustments against RZD’s monopoly. For this reason, most railcar manufacturers have been producing the same railcar for decades, but now since the market is changing, many manufacturers are exploring new options.

To the third question, Pavel Ivankin said since the railcars are limited by their infrastructure, there is no use in improving the railcars if the tracks cannot handle the increased load. Though the advancements made by NGRs are an improvement, Mr. Ivankin suggests that manufacturers need to increase the body volume and payload capacity of the railcars even more. However, in the next five years, he said, this is not feasible. Ivankin discussed the long term plan for RZD is to upgrade the tracks to support 35 tonnes per axle by 2020.

After question four was asked, Mr. Ivankin listed the following important parameters: axle load, dimensions, volume, metal limits for sides, and tare weight. One way to reduce tare weight is to use a different material. Ivankin said that ideally one would want a 95 tonne net payload capacity. The problem with using a different material is most materials do not qualify for the stress test, even if they are lighter. The castings for the bogies weight between 7 and 9 tonnes and each track piece weighs 5 tonnes.

Next, Ivankin reminded us though all of these factors are important to defining a NGR, only a few of them are recognized as a NGR by the government. The government is incentivizing these new railcars and there are discounts on empty runs. Though these incentives are good, the market is falling and less consumable goods need to be shipped, which means less railcars are needed.

Ivankin then expressed that NGRs are only cheaper than regular railcars in the first three years of its service life. After three years it becomes the same as regular gondolas. The only difference in cost are the subsidies granted by the government if the railcar is a government recognized NGR. Currently, UVZ and UWC are the only government supported NGRs.

From this, we asked question five and Ivankin confirmed the new RZD president's continued support for NGRs. The only reason RZD would not support the development of NGRs is because of the large investment needed. However, RZD will benefit from NGRs because there will be less railcars in operation therefore making the railways easier to manage. The empty rate for a railcar is 6-8% less for NGRs because it is paid for by railcar and not by tonnage. Because of this, the more that is loaded onto a railcar the more profitable it is.

Appendix F: Fuel Analysis Calculations

Coal

Table 14: Coal Fuel Analysis

Assumptions		**Material:**		Coal	
Train Effieciency (ton-mile/gallon)	246	Bulk Density (kg/m^3)		833	
Kliometers to Travel	5,000	Amount (tonnes)		10,000	
Ton miles / gallon to kg km / L	386	Space Needed (m^3)		12,004.80192	
Efficency (kg-km / L)	94,995	NGR Axle Load (tonnes)		23.5	
		OGR Axle Load (tonnes		25	

Limits for the Old Car						
10,000	tonnes	70	tonnes per car	=	144	cars
12,005	m^3	88	m^3	=	136	cars
				Greater:	144	
Limits for New Car						
10,000	tonnes	75	tonnes per car	=	133	cars
12,005	m^3	92	m^3	=	130	cars
				Greater:	133	

	Train Mass	**Train Kilogram Kilometrs (KgKm)**		**Liters of Fuel Used**
OGR (kg)	13,381,295	66,906,474,820		704,313.0825
NGR (kg)	13,333,333.3	66,666,666,667		701,788.6628
			Difference:	-2,524.41965
			Percent:	-0.358422939

Coarse Sawdust

Table 15: Coarse Sawdust Fuel Analysis

Assumptions			**Material:**		Coarse Sawdust
Train Effieciency (ton-mile/gallon)		246	Bulk Density (kg/m^3)		400
Kliometers to Travel		5,000	Amount (tonnes)		10,000
Ton miles / gallon to kg km / L		386	Space Needed (m^3)		25,000
Efficency (kg-km / L)		94,995	NGR Axle Load (tonnes)		23.5
			OGR Axle Load (tonnes		25

Limits for the Old Car

10,000	tonnes	70	tonnes per car	=	144	cars
25,000	m^3	88	m^3	=	284	cars
				Greater:	284	

Limits for New Car

10,000	tonnes	75	tonnes per car	=	133	cars
25,000	m^3	92	m^3	=	272	cars
				Greater:	272	

	Train Mass	**Train Kilogram Kilometrs (KgKm)**		**Liters of Fuel Used**
OGR (kg)	16,676,136	83,380,681,818		877,734.2579
NGR (kg)	16,793,478.3	83,967,391,304		883,910.4489
			Difference:	6,176.190986
			Percent:	0.703651581

Appendix G: Service Life Characteristics

Table 16: Service Life Characteristics

	Service life, years	Years to depot repair	Km to depot repair	Years to capital	Wheelset replacement term, years	Current repair, times per year	Bearings replacement term, years
New generation railcar (NGR)	32	4	500,000	16	8	-	8
Old generation railcar (OGR)	22	3	250,000	11	7	1	5

Table 17: Maintenance Occurance per Year

# of depot repairs during service life	# of capital repairs during service life	# of wheelset replacements during service life	Current repair times per life	# of bearings replacements during service life
8	1	16	11	3
10	1	12	22	4

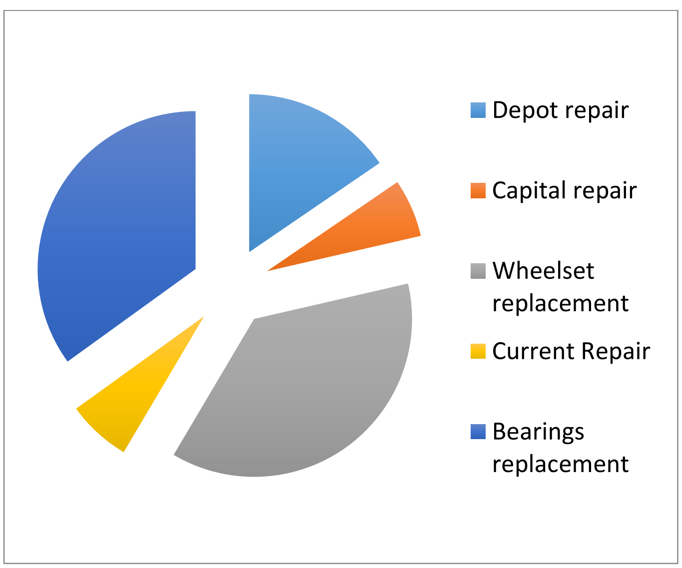

Figure 11: Comparison of Maintenance Costs

Table 18: Maintenance Costs During Service Life

Maintenance costs during service life:	NGR	OGR
Depot repair	520000	650000
Capital repair	200000	100000
Wheelset replacement	1248000	660000
Current Repair	220000	330000
Bearings replacement	1176000	160000
Total	3364000	1900000

Appendix H: Calculations

This appendix shows how select important metrics were calculated.

42 Percent of Railcars need to be replaced:

135632/325,408   = 42%

The average age of railcars is 14.8 years:

Total Weighted Age:

4,821,248

Division

4,821,248 / 325,408 = 14.8 years

Railcar Aging Source

Age September 2015	# of gondolas with this age	Age * Number of Cars
0	2,020	-
1	16,026	16,026
2	17,536	35,072
3	30,211	90,633
4	28,145	112,580
5	27,803	139,015
6	5,934	35,604
7	15,388	107,716
8	12,220	97,760
9	8,187	73,683
10	11,440	114,400
11	8,134	89,474
12	2,507	30,084
13	621	8,073
14	419	5,866
15	310	4,650

16	227	3,632
17	193	3,281
18	276	4,968
19	443	8,417
20	530	10,600
21	723	15,183
22	3,498	76,956
23	6,229	143,267
24	12,999	311,976
25	13,568	339,200
26	13,503	73,683
27	12,628	340,956
28	16,292	456,176
29	11,508	333,732
30	10,994	329,820
31	9,937	308,047
32	8,971	287,072
33	6,084	200,772
34	3,321	112,914
35	1,907	66,745
36	1,631	58,716
37	1,147	42,439
38	842	31,996
39	448	17,472
40	77	3,080
41	10	410
42	6	252
43	5	215
44	6	264
45	5	225
46	6	276
47	5	235
48	5	240
49	-	-
50	-	-
n\a	483	
Total	**325,408**	**4,543,853**

Appendix I: Financial Charts

Scrap Scenarios

Table 19: Scrap with 0% Financing

0%	First Year	Years after	After Break-even
Category	Rubles / Year	Rubles / Year	Rubles / Year
New gondola price	2,100,000	2,100,000	2,100,000
Scrap value	130,000	130,000	-
Financing %	0%	0%	0%
Price for Interest	-	-	-
Loan interest rate (Mosprime 3M + 3%)	15%	15%	0%
State subsidy	6%	0%	0%
Net rate	9%	15%	0%
Interest Yearly	-	-	-
Tax shield, Interest	-	-	-
Interest actual	-	-	-
Depreciation	57,813	57,813	57,813
Depreciation shield	11,563	11,563	11,563
Maintenance avg per year	105,125	105,125	105,125
Total costs per year	93563	93563	93563
Daily Rate	800	800	800
Total Income per Year	292000	292000	292000
Net First Year	198438	198438	198438
Break Even	*10*		
Years Remaining	*22*		
Net Profit	*4380000*		

Table 20: Scrap with 25% Financing

	25%	First Year	Years after	After Break-even
Category		Rubles / Year	Rubles / Year	Rubles / Year
New gondola price		#######	#######	#######
Scrap value		130,000	130,000	-
Financing %		25%	25%	0%
Price for Interest		492,500	492,500	-
Loan interest rate (Mosprime 3M + 3%)		15%	15%	0%
State subsidy		6%	0%	0%
Net rate		9%	15%	0%
Interest Yearly		44,128	73,678	-
Tax shield, Interest		8,826	14,736	-
Interest actual		35,302	58,942	-
Depreciation		57,813	57,813	57,813
Depreciation shield		11,563	11,563	11,563
Maintenance avg per year		105,125	105,125	105,125
Total costs per year		128865	152505	93563
Daily Rate		800	800	800
Total Income per Year		292000	292000	292000
Net First Year		163135	139495	198438
Break Even		*14*		
Years Remaining		*18*		
Total Profit		*3581223*		

Table 21: Scrap with 50% Financing

	50%	First Year	Years after	After Break-even
Category		Rubles / Year	Rubles / Year	Rubles / Year
New gondola price		#######	#######	#######
Scrap value		130,000	130,000	-
Financing %		50%	50%	0%
Price for Interest		985,000	985,000	-
Loan interest rate (Mosprime 3M + 3%)		15%	15%	0%
State subsidy		6%	0%	0%
Net rate		9%	15%	0%
Interest Yearly		88,256	147,356	-
Tax shield, Interest		17,651	29,471	-
Interest actual		70,605	117,885	-
Depreciation		57,813	57,813	57,813
Depreciation shield		11,563	11,563	11,563
Maintenance avg per year		105,125	105,125	105,125
Total costs per year		164167	211447	93563
Daily Rate		800	800	800
Total Income per Year		292000	292000	292000
Net First Year		127833	80553	198438
Break Even		*24*		
Years Remaining		*8*		
Total Profit		*1613477*		

Table 22: Scrap with 75% Financing

	75% First Year	Years after	After Break-even
Category	Rubles / Year	Rubles / Year	Rubles / Year
New gondola price	#######	#######	2,100,000
Scrap value	130,000	130,000	-
Financing %	75%	75%	0%
Price for Interest	#######	#######	-
Loan interest rate (Mosprime 3M + 3%)	15%	15%	0%
State subsidy	6%	0%	0%
Net rate	9%	15%	0%
Interest Yearly	132,384	221,034	-
Tax shield, Interest	26,477	44,207	-
Interest actual	105,907	176,827	-
Depreciation	57,813	57,813	57,813
Depreciation shield	11,563	11,563	11,563
Maintenance avg per year	105,125	105,125	105,125
Total costs per year	199470	270390	93563
Daily Rate	800	800	800
Total Income per Year	292000	292000	292000
Net First Year	92530	21610	198438
Break Even	*88*		
Years Remaining	*-56*		
Total Profit	*-1.1E+07*		

Table 23: Scrap with 100% Financing

	100%	First Year	Years after	After Break-even
Category		**Rubles / Year**	**Rubles / Year**	**Rubles / Year**
New gondola price, RUR		2,100,000	2,100,000	2,100,000
Scrap value		130,000	130,000	-
Financing %		100%	100%	0%
Price for Interest		1,970,000	1,970,000	-
Loan interest rate (Mosprime 3M + 3%)		15%	15%	0%
State subsidy		6%	0%	0%
Net rate		9%	15%	0%
Interest Yearly		176,512	294,712	-
Tax shield, Interest		35,302	58,942	-
Interst actual		141,210	235,770	-
Depreciation		57,813	57,813	57,813
Depreciation shield		11,563	11,563	11,563
Maintaince avg per year		105,125	105,125	105,125
Total costs per year		234772	329332	93563
Daily Rate		800	800	800
Total Income per Year		292000	292000	292000
Net First Year		57228	-37332	198438
Break Even		*-50*		
Years Remaining		*82*		
Total Profit		*16318837.1*		

No Scrap Scenarios

Table 24: No Scrap with 0% Financing

Category	0% First Year Rubles / Year	Years after Rubles / Year	After Break-even Rubles / Year
New gondola price	2,100,000	2,100,000	2,100,000
Scrap value	-	130,000	-
Financing %	0%	0%	0%
Price for Interest	-	-	-
Loan interest rate (Mosprime 3M + 3%)	15%	15%	0%
State subsidy	6%	0%	0%
Net rate	9%	15%	0%
Interest Yearly	-	-	-
Tax shield, Interest	-	-	-
Interest actual	-	-	-
Depreciation	57,813	57,813	57,813
Depreciation shield	11,563	11,563	11,563
Maintenance avg per year	105,125	105,125	105,125
Total costs per year	93563	93563	93563
Daily Rate	800	800	800
Total Income per Year	292000	292000	292000
Net First Year	198438	198438	198438
Break Even	*11*		
Years Remaining	*21*		
Total Profit	*4250000*		

Table 25: No Scrap with 25% Financing

25%	First Year	Years after	After Break-even
Category	Rubles / Year	Rubles / Year	Rubles / Year
New gondola price	#######	#######	#######
Scrap value	-	130,000	-
Financing %	25%	25%	0%
Price for Interest	525,000	492,500	-
Loan interest rate (Mosprime 3M + 3%)	15%	15%	0%
State subsidy	6%	0%	0%
Net rate	9%	15%	0%
Interest Yearly	47,040	73,678	-
Tax shield, Interest	9,408	14,736	-
Interest actual	37,632	58,942	-
Depreciation	57,813	57,813	57,813
Depreciation shield	11,563	11,563	11,563
Maintenance avg per year	105,125	105,125	105,125
Total costs per year	131195	152505	93563
Daily Rate	800	800	800
Total Income per Year	292000	292000	292000
Net First Year	160806	139495	198438
Break Even	*15*		
Years Remaining	*17*		
Total Profit	*3392979*		

Table 26: No Scrap with 50% Financing

	50%	First Year	Years after	After Break-even
	Category	Rubles / Year	Rubles / Year	Rubles / Year
	New gondola price	#######	#######	#######
	Scrap value	-	130,000	-
	Financing %	50%	50%	0%
	Price for Interest	#######	985,000	-
	Loan interest rate (Mosprime 3M + 3%)	15%	15%	0%
	State subsidy	6%	0%	0%
	Net rate	9%	15%	0%
	Interest Yearly	94,080	147,356	-
	Tax shield, Interest	18,816	29,471	-
	Interest actual	75,264	117,885	-
	Depreciation	57,813	57,813	57,813
	Depreciation shield	11,563	11,563	11,563
	Maintenance avg per year	105,125	105,125	105,125
	Total costs per year	168827	211447	93563
	Daily Rate	800	800	800
	Total Income per Year	292000	292000	292000
	Net First Year	123174	80553	198438
	Break Even	*26*		
	Years Remaining	*6*		
	Total Profit	*1281750*		

Table 27: No Scrap with 75% Financing

	75%	First Year	Years after	After Break-even
Category		Rubles / Year	Rubles / Year	Rubles / Year
New gondola price		#######	#######	2,100,000
Scrap value		-	130,000	-
Financing %		75%	75%	0%
Price for Interest		#######	#######	-
Loan interest rate (Mosprime 3M + 3%)		15%	15%	0%
State subsidy		6%	0%	0%
Net rate		9%	15%	0%
Interest Yearly		141,120	221,034	-
Tax shield, Interest		28,224	44,207	-
Interest actual		112,896	176,827	-
Depreciation		57,813	57,813	57,813
Depreciation shield		11,563	11,563	11,563
Maintenance avg per year		105,125	105,125	105,125
Total costs per year		206459	270390	93563
Daily Rate		800	800	800
Total Income per Year		292000	292000	292000
Net First Year		85542	21610	198438
Break Even		*94*		
Years Remaining		*-62*		
Total Profit		*-1.2E+07*		

Table 28: No Scrap with 100% Financing

	100%	First Year	Years after	After Break-even
Category		**Rubles / Year**	**Rubles / Year**	**Rubles / Year**
New gondola price, RUR		2,100,000	2,100,000	2,100,000
Scrap value		-	130,000	-
Financing %		100%	100%	0%
Price for Interest		2,100,000	1,970,000	-
Loan interest rate (Mosprime 3M + 3%)		15%	15%	0%
State subsidy		6%	0%	0%
Net rate		9%	15%	0%
Interest Yearly		188,160	294,712	-
Tax shield, Interest		37,632	58,942	-
Interst actual		150,528	235,770	-
Depreciation		57,813	57,813	57,813
Depreciation shield		11,563	11,563	11,563
Maintaince avg per year		105,125	105,125	105,125
Total costs per year		244091	329332	93563
Daily Rate		800	800	800
Total Income per Year		292000	292000	292000
Net First Year		47910	-37332	198438
Break Even		*-54*		
Years Remaining		*86*		
Total Profit		*17059379.3*		

Appendix J: EIOLCA

As mentioned in Chapter 3, we attempted to use Carnegie Mellon's Economic Input Output Life Cycle Analysis tool to obtain estimates on environmental and economic impact. The tool takes the value of product desired and displays estimated values for spending in other sectors of the economy. These monetary values are then correlated to carbon dioxide emissions. However, no model was available for Russia. A world view point was attempted by running the tool with different countries and comparing the results. The models however differed in the categorizations of activity by sector e.g. including locomotives in rolling stock production. Furthermore, the countries differed greatly in years that the models used for the data, such as 2002 for the USA and 1995 for Germany. This was deemed unacceptable for analysis and no useful conclusion could be drawn for the production of new generation railcars. We assumed that 135,632 would be replaced with NGRs valued at 2,100,000 Rubles. For a more accurate comparison, current value of the Ruble was converted to each economic model's native currency and depreciated to the value at the model's year of collection. The methodology is included as Appendix K and the results are included as Appendix L. Although the results are not directly applicable, they point out an interesting dynamic for the rail industry in the rest of the world.

Appendix K EIOLCA Methods

In order to determine the external impact that Russia will have during the transition to NGRs, we decided to look into broad scale economic and environmental factors. Life cycle assessment captures the complex relationship between economic activity in a sector with the environment and other involved industries. Carnegie Mellon's EIOLCA tool proved to be invaluable in creating usable estimates (Carnegie Mellon University, 2015). Since no data were available for Russia specifically, global vantage point was taken using the following models:

- US National Producer Price Models
    - US 2002 (428 sectors) Producer
- International Producer Models
    - Germany [1995] (58 sectors) Producer
    - Spain 2000 (73 sectors) Producer
    - Canada 2002 (105sectors) Producer
    - China 2002 (122 sectors) Producer

Each model is a large scale snapshot of how much money flowed from sector to sector and how the environment was affected by each sector of each industry. The tool relies on an estimate of induced economic activity, or how much money was generated by one sector of the economy (Carnegie Mellon University, 2015). The economic activity was estimated by multiplying the average cost of a next generation railcar by the maximum number of units that would be replaced or 135,632. We then obtained environment impact in terms of air pollutants from the assumed economic activity. No environmental data was available for Spain.

The data were then brought from the tool and put into a Microsoft Excel spreadsheet for further analysis to compare and identify areas of concern. The data gathered by EIOLCA were then compared to energy use reduction by use of NGRs. Specific energy use from the complete life cycle of each car type was unfortunately too expensive to gather accurate data; according to Dassault Systèmes (2015) full assessment ranges in the tens of thousands of United States dollars.

Appendix L: EIOLCA Results

The following tables were obtained from Carnegie Mellon’s EIOLCA tool and served as source data. The tool can be found at http://www.eiolca.net/.

Germany Economic

	Germany 1995 Sector	TotalEconomic$mill	Gross StateProduct$mill	DirectEconomic$mill	DirectEconomic%
	Total for all sectors	*7910*	*3100*	*5920*	*74.8*
20	Manufacture of structural metal products, rolling stock, railroad equipment	4190	1570	4140	98.9
55	Other market services, etc.	722	442	350	48.4
16	Manufacture of iron and steel	515	68.8	227	44.1
43	Services of wholesale trade, etc., recovery	274	190	172	62.7
21	Manufacture of machinery and equipment	235	86.4	163	69.4
19	Manufacture of drawing plants products, cold rolling mills, etc.	193	81.6	140	72.4
17	Manufacture of non-ferrous metals, semifinished products thereof	146	19.4	80.8	55.4
26	Manufacture of electrical machinery, equipment and appliances	139	46	75.9	54.7
28	Manufacture of tools and finished metal products	125	45.6	95.7	76.8
48	Other transport services	122	55.7	58.7	48.3

Germany Air Pollutants

	Germany 1995 Sector	SO2mt	COmt	NOxmt	VOCmt	Leadmt	PM10mt
	Total for all sectors	*20100*	*22500*	*14000*	*8410*	*1.11*	*4740*
20	Manufacture of structural metal products, rolling stock, railroad equipment	19100	20900	12200	7110	0.381	3220
26	Manufacture of electrical machinery, equipment and appliances	209	78.2	164	246	0.003	17.6
34	Printing and reproduction	146	83.1	142	13.2	0.014	55.5
3	Production and distribution of electricity,steam, hot water	117	162	752	112	0	50.7
5	Production and distribution of water	52.7	38.3	40.7	3.23	0.155	26.8
30	Wood working	42.9	34.2	24	19	0	4.1
7	Production of other mining products (excl. coal, crude petroleum, natural g	39.6	27.6	66.6	19.7	0	0.8
17	Manufacture of non-ferrous metals, semifinished products thereof	34.7	31.2	4.57	6.7	0	0.466
36	Manufacture of textiles	31.7	45.6	3.27	3.14	0.093	2.45
55	Other market services, etc.	28.9	160	14.3	126	0.433	1.8

Germany Green House Gasses

	Germany 1995 Sector	GWPMTCO2E	CO2MTCO2E	CH4MTCO2E	N2OMTCO2E	CFCsMTCO2E
	Total for all sectors	*3620000*	*3310000*	*293000*	*2390*	*6360*
20	Manufacture of structural metal products, rolling stock, railroad equipment	3180000	2920000	256000	1750	1290
26	Manufacture of electrical machinery, equipment and appliances	94100	87000	5130	56.6	1920
21	Manufacture of machinery and equipment	36800	33400	3400	48.5	0
16	Manufacture of iron and steel	35000	31800	3170	59.8	0
55	Other market services, etc.	30800	27700	3070	75.3	0
34	Printing and reproduction	29200	26500	2760	22.9	0.255
43	Services of wholesale trade, etc., recovery	19300	16500	2690	71.4	0
8	Extraction of crude petroleum, natural gas	18200	16700	1510	7.03	0
28	Manufacture of tools and finished metal products	16600	15500	1110	14.5	0
19	Manufacture of drawing plants products, cold rolling mills, etc.	16100	13900	2180	54.6	0

Spain Economic

	Spain 2002 Sector	TotalEconomic€ mill	Value Added€ mill	DirectEconomic€ mill	DirectEconomic%
	Total for all sectors	*6140*	*3200*	*4400*	*71.7*
46	Transporte por ferrocarril	3250	2060	3250	99.9
37	Fabricaci—n de otro material de transporte	371	105	290	78
9	Producci—n y distribuci—n de energ'a elŽctrica	281	120	203	72.3
40	Construcci—n	278	102	195	70
60	Otras actividades empresariales	244	132	110	45.3
8	Coquer'as, refino y combustibles nucleares	120	14	46.6	39
50	Actividades anexas a los transportes	97.1	36.9	40.9	42.1
30	Fabricaci—n de productos met‡licos	94.4	33.6	0.311	0.33
29	Metalurgia	93.5	27	0.467	0.499
5	Extracci—n de crudos de petr—leo y gas natural. Extracci—n de uranio y torio	88.9	31.3	0	0

Canada Economic

	Canada 2002 Sector	TotalEconomic$mill	DirectEconomic$mill	DirectEconomic%
	Total for all sectors	*9430*	*7110*	*75.4*
3365	Railroad rolling stock manufacturing	8090	6830	84.5
3310	Primary metal manufacturing	170	65.9	38.7
2122	Metal ore mining	110	0.304	0.276
3320	Fabricated metal product manufacturing	79.1	32.7	41.3
2121	Coal mining	59	0.172	0.291
335A	Electrical equipment and component manufacturing	46.2	9.24	20
5610	Administrative and support services	40.3	17.9	44.3
3330	Machinery manufacturing	32.1	10.3	32.2
327A	Miscellaneous non-metallic mineral product manufacturing	31.1	2.07	6.68
325A	Miscellaneous chemical product manufacturing	26.8	4.21	15.7

Canada Air Pollutants

	Canada 2002 Sector	COmt	NOxmt	SO2mt	PM10mt	VOCmt
	Total for all sectors	*2390*	*857*	*10400*	*253*	*310*
3310	Primary metal manufacturing	1680	74.7	691	29.7	28.7
2122	Metal ore mining	372	192	9100	136	24.2
3113	Sugar and confectionery product manufacturing	73.7	120	0.545	0.225	4.82
327A	Miscellaneous non-metallic mineral product manufacturing	30	56.6	23.4	18.6	4.73
5620	Waste management and remediation services	29.4	8.19	4	2.19	14.5
3221	"Pulp, paper and paperboard mills"	25.7	11.2	13.2	4.34	4.65
3253	"Pesticides, fertilizer and other agricultural chemical manuf	23.4	38.8	9.62	2.72	4
3241	Petroleum and coal products manufacturing	23.2	9.59	31.2	1.6	5.73
3273	Cement and concrete product manufacturing	18.2	30.3	34.3	2.2	0.402
3251	Basic chemical manufacturing	17.1	27.3	24.2	3.53	10.6

Canada Green House Gasses

	Canada 2002 Sector	CO2kMTCO2E	CH4kMTCO2E	N2OkMTCO2E	GWPkMTCO2E
	Total for all sectors	*586*	*63.2*	*17.2*	*667*
3365	Railroad rolling stock manufacturing	123	0.073	0.898	124
3310	Primary metal manufacturing	106	0.035	0.354	106
2211	"Electric power generation, transmission and distribution"	59.9	0.051	0.331	60.3
2122	Metal ore mining	42.1	0.041	1.63	43.8
3253	"Pesticides, fertilizer and other agricultural chemical manuf	34.6	0.004	3.15	37.8
2121	Coal mining	32.2	38	1.93	72.1
327A	Miscellaneous non-metallic mineral product manufacturing	23.8	0.006	0.068	23.9
4860	Pipeline transportation	17.3	10.1	0.093	27.5
3251	Basic chemical manufacturing	11.7	0.004	0.045	11.8
4820	Rail transportation	11.2	0.014	1.31	12.5

China Economic

China 2002		
	Sector	Total Economic $mill
	Total for all sectors	*79900*
66	Railroad transport equipment	29100
56	Steel-processing	4770
63	Other general industrial machinery	3020
85	Electricity and steam production and supply	2880
101	Wholesale and retail trade	2810
55	Steel-smelting	2120
73	Other electric machinery and equipment	1870
60	Metal products	1640
36	Petroleum refining	1290
58	Nonferrous metal smelting	1240

China Air Pollutants

China 2002			
	Sector	SO2 MT	NOx MT
	Total for all sectors	*101000*	*39900*
85	Electricity and steam production and supply	45800	26100
58	Nonferrous metal smelting	20000	251
59	Nonferrous metal processing	15900	200
56	Steel-processing	3810	1820
66	Railroad transport equipment	2700	1540
55	Steel-smelting	1700	813
7	Coal mining and processing	1030	518
38	Raw chemical materials	918	278
52	Fireproof products	708	311
43	Chemicals for special usages	708	214

China Green House Gasses

China 2002		
	Sector	MTCO2E
	Total for all sectors	*11300000*
85	Electricity and steam production and supply	5290000
56	Steel-processing	1830000
55	Steel-smelting	816000
66	Railroad transport equipment	384000
54	Iron-smelting	290000
52	Fireproof products	227000
50	Glass and glass products	226000
53	Other non-metallic mineral products	191000
57	Alloy iron smelting	159000
8	Crude petroleum products and Natural gas p	152000

USA Economic

USA 2002								
	Sector	Total Economic$mill	Total Value Added$mill	Employee Comp VA$mill	Net Tax VA$mill	Profits VA$mill	Direct Economic$mill	Direct Economic%
	Total for all sectors	*7150*	*3060*	*1840*	*109*	*1110*	*5090*	*71.2*
336500	Railroad rolling stock manufacturing	3280	1200	687	6.72	505	3260	99.1
550000	Management of companies and enterprises	346	214	181	5.26	27.6	210	60.6
420000	Wholesale trade	294	204	111	47.9	45.6	151	51.6
332310	Plate work and fabricated structural product manufacturing	212	78.3	57.9	0.948	19.5	184	86.7
331110	Iron and steel mills	157	42.6	31.2	1	10.4	58.4	37.1
335314	Relay and industrial control manufacturing	150	68.3	41.5	0.343	26.5	124	83.1
331411	Primary smelting and refining of copper	80.5	20.4	5.22	0.859	14.3	40.8	50.7
332600	Spring and wire product manufacturing	73.5	32.4	20.9	0.262	11.2	52.5	71.4
335120	Lighting fixture manufacturing	66.1	27.6	15	0.196	12.4	58.4	88.3
531000	Real estate	63.8	50.3	4.69	6.44	39.2	10.1	15.8

USA Air Pollutants

USA 2002								
	Sector	COt	NH3t	NOxt	PM10t	PM2.5t	SO2t	VOCt
	Total for all sectors	*6920*	*126*	*4980*	*1240*	*536*	*5060*	*3450*
331110	Iron and steel mills	2140	6.09	320	88.9	71.1	239	72.2
484000	Truck transportation	651	1.85	688	197	34.4	14.2	73.1
33131A	Alumina refining and primary aluminum production	406	0.84	17.6	12.9	8.24	129	5.28
331200	Iron, steel pipe and tube manufacturing from purchased ste	316	1.01	46.6	15.4	12.1	35	20.4
532400	Commercial and industrial machinery and equipment rental	271	0.016	4.18	0.871	0.77	1.59	22.1
221200	Natural gas distribution	235	0.058	10.4	0.68	0.615	3.36	10.6
336500	Railroad rolling stock manufacturing	202	4	513	67.1	36.6	995	2290
420000	Wholesale trade	170	0.537	167	46.3	8.7	11.4	89.9
811400	Household goods repair and maintenance	155	0.006	2.2	0.473	0.433	0.144	12.9
211000	Oil and gas extraction	138	0.097	101	0.942	0.809	6.77	141

USA Green House Gasses

USA 2002							
	Sector	Totalt CO2e	CO2 Fossilt CO2e	CO2 Processt CO2e	CH4t CO2e	N2Ot CO2e	HFC/PFCst CO2e
	Total for all sectors	*1620000*	*1180000*	*293000*	*97100*	*15100*	*27500*
221100	Power generation and supply	473000	466000	0	1280	2890	3000
331110	Iron and steel mills	429000	162000	264000	2610	0	0
484000	Truck transportation	78500	78500	0	0	0	0
336500	Railroad rolling stock manufacturing	67600	67600	0	0	0	0
211000	Oil and gas extraction	54500	15400	9990	29200	0	0
482000	Rail transportation	41400	41400	0	0	0	0
481000	Air transportation	36100	36100	0	0	0	0
212100	Coal mining	31100	3500	0	27500	0	0
324110	Petroleum refineries	29200	29100	0	90.5	0	0
331411	Primary smelting and refining of copper	23300	23300	0	0	0	0