# The Capabilities and Economics of Specialty Ballast Excavation

## Advanced Methodology and Techniques for Specialty Ballast Remediation on MRS Railway

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## Abstract

This study focuses on the efficiency gains and increased versatility obtained through the use of vacuum excavation technology to repair specialty track work areas such as bridges, tunnels, and switches. Heavier axle loads coupled with progressive increases in traffic volumes have intensified the demand for track maintenance. Specialty track works are among the most expensive part of any railroad maintenance budget yet commonly the most neglected as they create unique challenges. Traditional methods of repairing specialty track works require significant resources and track outages. As a result, maintenance is often delayed in these areas, resulting in a variety of debilitating ballast and subgrade problems. Specialized vacuum excavation equipment with unique flexibility has led to non-evasive maintenance techniques that allow railways to optimize their maintenance activities and avoid service interruptions. Additionally, utilizing vacuum excavation provides improved remediation of the track structure, increasing the load bearing capacity, restoring desired drainage, and increasing the overall maintenance completion rate in these difficult areas.

## Introduction

Specialty Trackwork is an expensive part of any railroad's infrastructure. In North America Special Trackwork annual cost, for just turnouts and diamonds, is more than $1 billion. Maintenance and train delay represent over 50% of that cost. Maintenance of Specialty Trackwork represents approximately 5% of maintenance budgets and up to 50% of train delays are attributed to Specialty Trackworks. The payback for keeping Specialty Trackwork maintained can be significant.

Ballast has two main functions in its interaction with Specialty Trackwork structures. First ballast needs to anchor the track and provide resistance against lateral, longitudinal and vertical movement of ties and rail while distributing the applied load with diminished unit pressure to the subgrade beneath. The second important function of the ballast is to provide drainage. However, the repeated impact loading on the ballast, as trains pass, cause the sharp edges to break off and wear down into fines. These fines then begin to impede the drainage of the moisture. As the moisture and fines combine the ballast begins to lose its ability to provide the stability. This deterioration begins with the first load applied to the ballast as wheels begin rolling down the rails. If the fines and silt are not removed with routine maintenance the ballast loses its ability to restrain the track from lateral, longitudinal and vertical movement. If not corrected with ballast replacement, the probability of broken rails and derailments is high. Even with proper maintenance for drainage, over time the ballast will deteriorate and lose its ability to provide resistance to lateral, longitudinal and vertical movements because the sharp edges and corners of the ballast become worn over time and lose their interlocking strength thereby requiring ballast replacement.

The most effective means of restoring track performance on Specialty Trackworks is ballast replacement. Traditional ballast replacement practices are expensive, highly disruptive, often involves the removal of the superstructure so off-track equipment can be used to remove the ballast. In areas where off-track equipment use is not feasible, using manual labor or deploying an undercutter are options. Undercutters are designed for use in major track rehabilitation projects and are probably already overbooked for these major projects. If the Specialty Trackwork has restrictive clearances, the undercutter is not an option. Furthermore these processes render the track inaccessible, create significant track outages, and are resource intensive.

Specialty Ballast Remediation is the process of correcting the problem of poor or bad ballast conditions through ballast replacement and required drainage enhancements on Specialty Trackworks including switches, crossings, bridge decks, viaducts, tunnels, platforms, random mud spots or track with third rail electrification.

## MRS Logistica S.A. Overview

MRS Logistica SA (MRS) is a Brazil-based company engaged in transportation services. The company focuses on the public service of freight railroad transportation and is active in the control, operation and monitoring of the Southeastern Federal Railroad Network. The company has been in railway transportation of cargo including ore, finished steel products, cement, bauxite, pulp, green coke, containers and agricultural commodities, among others since 1996. It interconnects the Brazilian states of Minas Gerais, Rio de Janeiro and Sao Paulo, as well as ports of Rio de Janeiro, Guaiba, Itaguai and Santos. This region amasses approximately 55% of Brazil's gross domestic product and is home to the country's largest industries.

MRS Logistica S.A System

MRS Logistica SA has 1,643 kilometers (1,021 mi) of 1600 mm (63") track with 76 Km (47.2 mi) of tunnels and 32 Km (19.9 mi.) of closed platform bridges and viaducts. The track traverses through very rugged mountainous terrain which receives an average rainfall of 100 to 150 cm (40 to 60 in.) per year (See Appendix A for Annual Rainfall Map). Traffic density is very high on this track with axle loads of 32 tonnes (35 ton). These difficult conditions and the abundance of Specialty Trackwork assets i.e. tunnels, bridges, viaducts and switches require a tremendous effort to keep the track well maintained.

## MRS Logistica’s Challenge

Tunnel 9 Derailment

MRS Logistica realized it was time to find a better method of rehabilitating their Special Trackwork following a 2009 derailment in Tunnel 9 (see insert to right) caused by a broken rail as a result of ineffective ballast and drainage maintenance.

MRS Logistica had been performing the track maintenance manually but it was becoming very apparent the ballast and drainage maintenance being performed was not productive enough to keep up with the rate of deterioration plus it was not complete and the overall result was very ineffective. In fact the ballast condition had reached a point where it was jeopardizing the safety and reliability of the track.



MRS began to assess their needs. Their tunnels, bridges and viaducts were the highest priority. The system has 76 Km (47.2 mi) of tunnels and 32 Km (19.9 mi.) of bridges and viaducts that needed ballast replacement and with their current method of manual labor it would take an estimated 13.8 years to accomplish. Out of the entire system it was determined that 10 Km (6.2 mi.) of tunnels and 26 Km (16.2 mi.) of bridges and viaducts were critical to the success of MRS and needed immediate rehabilitation. To accomplish this would take an estimated 4.6 years with manual labor.

## MRS Logistica’s Search for New Specialty Trackworks Rehabilitation Method


Realizing the current method of Ballast and Drainage Maintenance on Specialty Trackwork assets was insufficient, MRS went on a mission to find a better and more productive method. An External Expert was hired for an opinion on their situation. A part of the External Expert’s opinion, relating to the concrete viaducts, recommended the complete removal of the existing badly contaminated ballast and replaced with good quality new ballast and a new track (ties and rail) at the same time. (See insert to right)

MRS also sent a team to North America to discover how one of the Class 1 railroads was cleaning their tunnels. On their visit they witnessed a Loram Railvac undercutting fouled track in a tunnel with tight restrictive clearances. In fact the conditions were very similar to those on MRS Logistica’s system. The track had serious drainage issues and the ballast was very wet and contaminated. The restrictive clearances were similar to those on the MRS. The MRS Exploratory Team realized that with a Railvac they could be more productive in maintaining the ballast in their tunnels and on their bridges and viaducts. With the Loram Railvac the opportunity to maintain their Specialty Trackwork assets to a higher standard was possible. The team’s next step was the development of a justification for the investment in equipment and training for the next generation of Specialty Trackwork Rehabilitation Methodology.

## MRS Logistica's Justification

Because the tunnels bridges and viaducts had been without effective maintenance for decades, the condition was jeopardizing the safety and reliability of the rail system. MRS realized the need was a complete change in the approach to Specialty Trackworks Ballast Maintenance. They needed a better method of restoring track performance that still included ballast replacement but was less expensive, less disruptive and required fewer resources. It would require the purchase of a Loram Railvac machine plus the operation and maintenance training of the Railvac.

MRS saw the Loram Railvac as a versatile machine with a tremendous amount of flexibility. It was designed to work as an undercutter, excavator, or high performance debris or Hazmat collector capable of working in open track areas as well as in the restrictive clearance environments that are commonly associated with Special Trackworks. The six (6) degrees of freedom on the nozzle (See Appendix A for examples) and the capability of rotating the nozzle 45° from vertical in all directions (See Appendix A for examples) would make it easy to reach those difficult spots when undercutting and trenching. The Railvac was also very versatile in handling the waste material. It could store 15 $m^3$ (20 $yd^3$) of material onboard, dispose of the material, onto the right of way, up to 9 m (30 ft.) either side of track center or transfer the material directly to a material handling car. The Railvac can also haul four full ballast cars at speeds up to 80 km/h (50 mph). (See Appendix A for examples)

In compacted ballast conditions, the Railvac's work arm could use its 2,270 kg (5,000 lbs.) of penetrating force and rotating nozzle to quickly break up material for quick disposal at a rate of 15 $m^3$/hr. (20 $yd^3$/hr.). (See Appendix A for examples)

The Railvac has the unique ability to access any location by rail, eliminating the need for off-road access equipment. It has the power and ruggedness to breakup compacted ballast. It has the flexibility to reach up to 4.5 m (15 ft.) to either side of the track center to clear ditches or unplug culverts with its nozzle but still has the gentleness and finesse necessary to uncover sensitive objects like buried communication wires, drainage tile, or switch componentry without the risk of damage. (See Appendix A for examples)

MRS recognized the Railvac as a machine that would allow them to provide an improved standard of Ballast Maintenance with minimal track disruption and extremely large reductions in resources.

In addition to the benefits Loram's Railvac provided, there must also be an economic justification for the investment as well. MRS Logistica's current method required a train to haul away the waste. They knew this requirement could be eliminated because Loram's Railvac offered many acceptable options for waste material handling.

MRS estimated an increase of 60% in productivity from 20 $m^3$/hr. (65.5 $ft.^3$ /hr.) to 32 $m^3$/hr. (105 $ft.^3$ /hr.) plus a 76% reduction of manpower. MRS had been using 50 people under their traditional method and they estimated 12 people would be required with the Railvac.

MRS estimated the unit cost of the Railvac at R$ 93.95 ($29.69 USD). This included the depreciation cost of the Railvac, operating expenses and wages of 12 people. Under MRS' traditional method the unit cost ranged from R$ 155.13 ($ 49.02 USD) on the low end up to R$ 425.44 ($ 134.43 USD). This range was dependent on the complexity of the ballast replacement work being completed. The average unit cost under the traditional method is R$ 290.29 ($ 91.73 USD). Comparing the average unit cost under the traditional method against the estimated unit cost of the Railvac results in a per unit savings of R$196.34/$m^3$ ($62.04 USD/$m^3$). With an annual production estimate of 12480 meters (40945 feet) the estimated annual savings would be R$ 2,450,260.80 ($ 774,228.51 USD). (See Appendix B for MRS comparisons)

## MRS Tunnel 12 Track Remediation Project Economic Comparison

Tunnel 12 of MRS Railway was chosen for a comparative study to determine the economics of the Railvac methodology versus the traditional method used at MRS. The length of Tunnel 12 is 2,233 m. (1.39 mi.). The last time Tunnel 12 was re-ballasted using their traditional method, it required 110 days of 8 hour duration with 50 workers for a total cost of R$ 950,000.00 ($ 300,200 USD).

Using the Railvac on the same tunnel of 2,233 m. (1.39 mi.) of track and 8 hour duration days changed the economics considerably. The project was completed in 14 days. The number of people used with the Railvac project was 12. The total cost of the project, using the Railvac, was R$209,790 ($66,290 USD).

This represents an 87% improvement in the number of days, a 76% reduction in the number of people required, and the total cost of the project improved by 78%. The cost savings for the project was R$740,210 ($233,910 USD).

The total hours worked with the Traditional Method was 44,000 hours (8 hour days; 110 days; 50 people) as compared to1,344 hours (8 hour days; 14 days; 12 people) using the Railvac. Productivity calculated as meters completed per hour worked improved 3,174% from 0.051 m/hr. to 1.66 m/hr. (See Appendix C for Economic Comparisons between Traditional Method and Railvac Method)

**MRS Ballast Removal on Double Track in Mountains**

On a recent track renewal project on double main track in the mountains between KM64 and KM110 the Railvac was spot cleaning only the very contaminated sections of track. The machine was operated by two people.

The production records for June 1 and June 2 show the machine worked 1 hr. and 49 minutes on June 1 and 3 hr. and 29 minutes on June 2, removing 39 $m^3$ and 91 $m^3$ respectively. For these two days of operation the average production was 24.53 $m^3$/hr.

June 1, 2015

16:21 - Start of work

**Km71+445 to 71+307 between the tracks = 34.5m3 in 60 minutes**
**Km71+445 to 71+429 right shoulder = 4.5m3 in 11 minutes**
**TOTAL = 39m3 in 1h11minutes – 2 full dumpings (7 min each dump)**
18:10pm - end of work

Work Location on June 1

June 2, 2015

14:51 pm - the start of work

**Right shoulder - km74 + 232 to 74 + 070**
**Left shoulder - km74 + 172 to 74 + 018**
**Total = 91m3 and 7 dumpings**

18:20 pm – end of the work

Work Location on June 2

One significant improvement since MRS began using the Railvac is the number of people operating the machine. When MRS first started they had four (4) people assigned to the machine. That number has been cut in half from 4 to 2 and the unit cost has improved 35% from R$ 93.95/$m^3$ to R$ 60.62/$m^3$ during the first two years of operation of the Railvac. (See Appendix D for pictures and chart)

## CN Bathurst Ore Impacted Ballast Removal

CN identified an environmental concern related to the transport of mined ore concentrate containing Pb, Zn, Cu and other heavy metals from 1964 to 2013. CN unit trains transported the ore concentrate a distance of 70km (44 miles) from a mine site through a CN Yard to a smelter site. The track is bordered by 1000 adjacent properties, a city and several towns, it crosses 51 mapped streams and six provincially designated environmentally significant areas and bisects a First Nation (tribe) property. The visible ore concentrate on the track was mapped at various times between 2010 and 2014. At the time of the mine site closure, visible ore concentrate was present within the gauge of 23km [14 miles] of track because of the accumulation of small particles escaping from the unit trains during transport.

In the fall of 2013 and winter 2014, a remedial plan to recover the visible ore concentrate was developed following CN's environmental strategy that is focused on safety, emissions reduction, waste management, and environmental stewardship. The planning process was proactive and involved: monthly meetings with the project team including various CN department representatives (e.g. Environment, Engineering, Mechanical, Legal, Public Relations, and Purchasing), an environmental engineering firm and Loram. This planning process was crucial to the success of the project. It included stakeholder engagement with consistent communication to regulators, local government, and the mine prior to starting the remedial work.

The remedial work was performed in the summer of 2014 using a Loram Railvac™, equipped with HEPA filters, and five Knapp cars supplied by CN. A total of 4,100 tonnes (4,500 tons) of recovered ore-impacted ballast was 1) excavated from the track by Loram's Railvac™, 2) transferred to the five Knapp cars and 3) transported to the Mine site by the Loram's Railvac™ for re-use (which resulted in greenhouse gas reduction of >300 tonnes of $CO_2$ equivalent). During the remediation process air quality protection measures were utilized to mitigate dust and real-time particulate matter monitoring was completed.

Utilizing the specialized rail bound equipment; the remedial work was completed successfully. There was no disruption to rail service and no complaints from the public. It also resulted in significant cost saving to CN because the project generated less waste material than conventional remedial techniques and was completed in four weeks versus the projected eight weeks.

## Loram Mud Spot Undercutting – Third Rail & Platform

In April, 2015 a Loram customer had a mud spot next to a platform on third rail electrified track. The length of track requiring ballast renewal was 7.5 m (24.6 ft.). The project scope included travel from tie-up spot to work location, de-energizing the third rail, unfastening the third rail from the ties, unloading new ties and associated hardware, undercutting the mud spot site, removing old ties and subsequent tie replacement, loading old ties on to truck crane bed, reattaching the third rail, ballast replacement, tamping, reenergizing the third rail, travel back to tie up spot and unloading hopper. The work window to complete this project was 4.5 hours.

Support equipment working with Loram's Railvac included a Hi-Rail Hydraulic Boom Truck with new ties, a Hi-Rail Material Handling Vehicle with new ballast and a Tamper.

Loram did a full undercut including the removal of the fast clips on the ties, dropping the ties from the rails, pushing the old ties onto the right-of-way and staging the new ties under the rail for installation. The work crew was able to safely install ties as the Railvac was completing the undercutting work, giving the Project Leader sufficient time to complete the job within the time limits. All of this work was done in 1 hour. Another 30 minutes was required to unload and tamp the new ballast. (See Appendix E for pictures of work).

## Additional Benefits

Loram's Railvac offers MRS Logistica, CN and all of its customers many additional benefits beyond the Tunnel, HazMat Cleanup, and Undercutting between a Platform and Third Rail Specialty Trackworks applications illustrated in this paper. It is an excellent machine for Ballast Excavation on Switches, Diamonds, Bridge Decks, and Viaducts or track with clearance restrictions.

The Railvac can also be used to dig trenches to drain water away from the track and into a drainage ditch. It can also dig trenches alongside the track or under the track to bury wires and cables. The Railvac can be used to uncover buried wires and cables without damaging them. The Railvac is great at cleaning up debris in yards and other areas where trash and debris accumulate. (See Appendix E for pictures of other Railvac activities)

## Summary

With the use of Loram's Railvac the CN (Canadian National Railway) was able to clean up an environmental concern safely with less waste than traditional methods and in 1/2 the expected time.

A 7.5 m (24.6 ft.) mud spot next to a platform and on third rail track was totally restored and back in service with one hour to spare of the 4.5 hour work window granted for the project.

The Railvac purchased by MRS in 2012 was a very good investment. The comparison of Tunnel 12 proved the economics of the Railvac methodology over the traditional method for MRS by reducing project duration 87%, reducing resource requirements 76% and increasing the productivity (work completed per total hours expended) by over 3000%. (See Appendix C for Economic Improvement Comparisons between Traditional Method and Railvac Method)

MRS tracked their productivity ($m^3$/hour) for one full year (March 26, 2013 to March 26, 2014). During this period MRS operated the Loram Railvac a total of 125 days and 243.75 hours. Its production, for that year, averaged 25.9 $m^3$/hr. MRS continues to make improvements in their productivity and have recently reduced the Railvac operating crew from four (4) to two (2) people.

These are just a few examples of how Railvac can help you keep your ballast maintained and healthy on all of your Specialty Trackworks while also saving you time, money and resources over the traditional methods of Specialty Ballast Remediation.

Let Loram's Railvac take your Specialty Trackworks from:

This

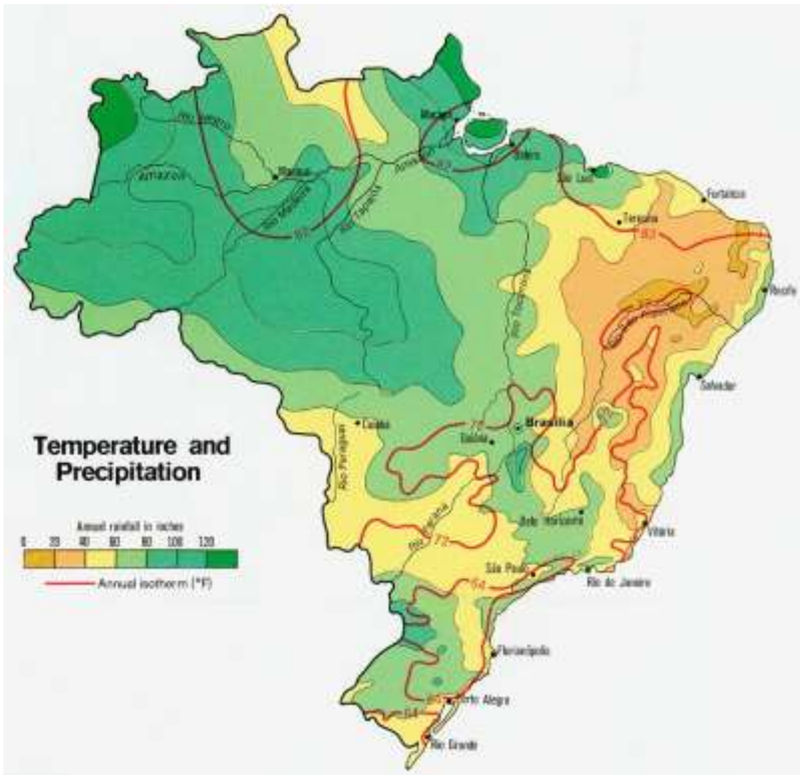
To This

To This

in less time, with fewer resources and less disruptions than traditional methods for your Specialty Trackworks Ballast Remediation Projects.

# Appendix A

1. Annual Rainfall Map




2. Six Degrees of Freedom Illustration:


3. Example of Nozzle at 45° from vertical

4. Material Handling Capabilities

Waste - Onboard

Waste to Material Handling Car

Waste to Right of Way

Pulling 4 Material Handling Cars

5. Examples of Rotating Nozzle

6. Examples of uncovering buried communication wires, trenching, and drainage work




# Appendix B

1. Comparison Estimates on two tunnels.

## Manual cleaning comparative x Mechanized

MRS

Location Considered: Tunnel of Goats

| Manual Labor(1) | | |
|---|---|---|
| Cleaning Extension– meters | 497 | |
| Range Required – hours | 38 | |
| Material removal with Train service (400 m³) | R$ | 15,346.38 |
| Cost – R$ | R$ | 92,446.36 |
| Unit cost considered | R$ | 155.13 |
| Annual production considered – meters | | 12,480 |
| **Annual Cost** | **R$1,936,022,40** | |

| Job Railvac | | |
|---|---|---|
| Cleaning Extension– meters | | 497 |
| Range Required – hours | | 17 |
| Material removal with Train service (400 m³) | | 0 |
| Cost – R$ | R$ | 46,692,51 |
| Unit cost considered | R$ | 93,95 |
| Annual production considered – meters | | 12,480 |
| **Annual Cost** | **R$ 1,172,496,00** | |

| | |
|---|---|
| **Value of the investment** | **R$12,928,500,00** |

## Manual cleaning comparative x Mechanized

MRS

*Comparative: ballast Cleaning 12 Tunnel*

| MANUAL LABOR | |
|---|---|
| The cleaning extension - meters | 2.233 |
| Days for execution ( 8 hours) | 110 |
| Range Required - hours | 880 |
| Number of Men | 50 |
| Total Cost | R$ 950.000,00 |

| | |
|---|---|
| Unit Cost | 425,4366321 |

| DESGUARN WORK THE VACUUM | |
|---|---|
| The cleaning extension - meters | 2.233 |
| Days for execution ( 8 hours) | 14 |
| Range Required - hours | 112 |
| Number of Men | 12 |
| Estimated Cost | R$ 209.790,35 |

| | |
|---|---|
| Estimated unit cost | 93,95 |

Fonte : Malha Ferroviária

NOTE: the difference in productivity between the two manual service Tunnels explained:-12 Tunnel is much larger (2 Km) and tighter feedback; -The service in the tunnel was 12 more complete, including drainage devices.

2. Picture of Traditional Method and Mechanized Method

Traditional Method

Mechanized Method

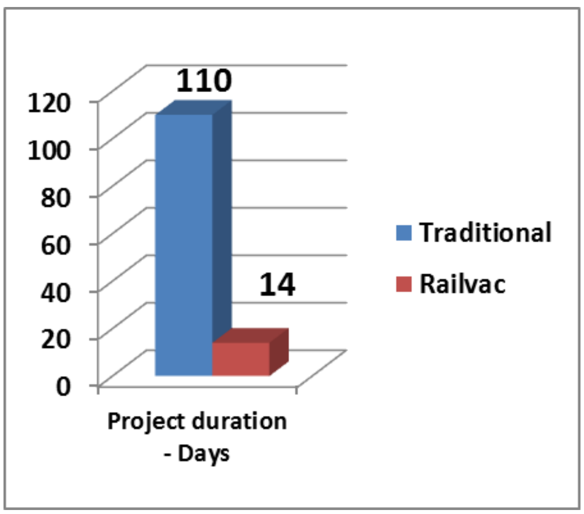
# Appendix C

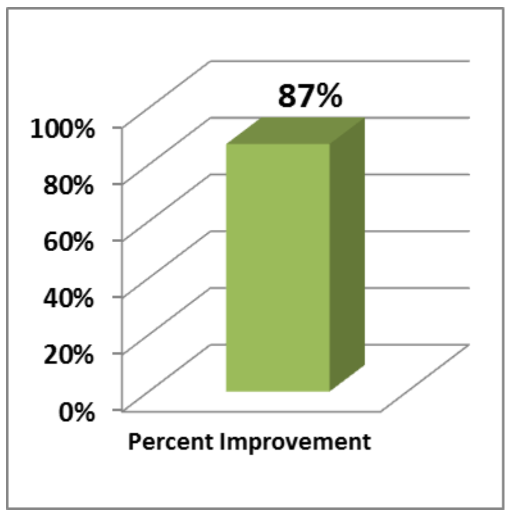
1. Tunnel 12 Economic Analysis Summary

| Tunnel 12 Economic Analysis | | | |
|---|---|---|---|
| | **Traditional** | **Railvac** | **% Improvement Railvac vs. Traditional** |
| Meters Reballasted | 2233 | 2233 | 0% |
| Project duration - Days | 110 | 14 | 87% |
| Hours per day | 8 | 8 | 0% |
| Number of Employees | 50 | 12 | 76% |
| Project duration - Hours | 880 | 112 | 87% |
| Total Labor Hours (1000) | 44 | 1.344 | 97% |
| Total Cost (1,000's)(R$) | R$ 950.00 | R$ 209.79 | 78% |
| Total Cost (USD) (1,000's) | $300.18 | $66.29 | 78% |
| Unit Cost (R$/m) | R$ 425.44 | R$ 93.95 | 78% |
| Unit Cost ($ USD/Meter) | $134.43 | $29.69 | 78% |
| Meters per hour worked | 50.750 | 1,661.458 | 3174% |
| Productivity increase | 3174% | | |

2. Project Duration Comparison

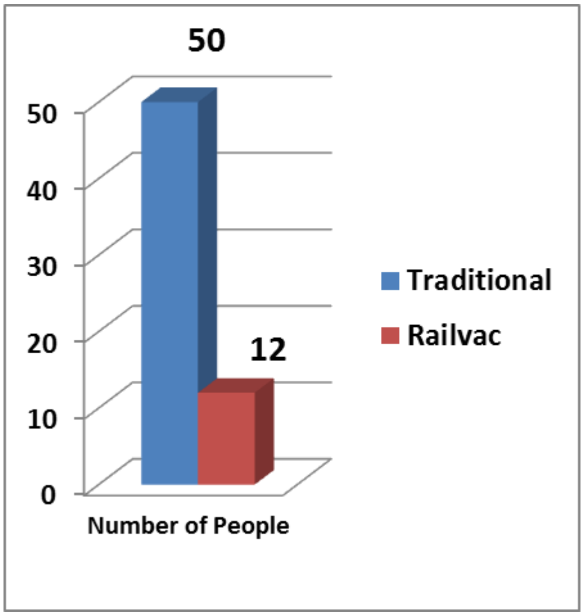
| | **Traditional** | **Railvac** | **% Improvement Railvac vs. Traditional** |
|---|---|---|---|
| Project duration - Days | 110 | 14 | 87% |

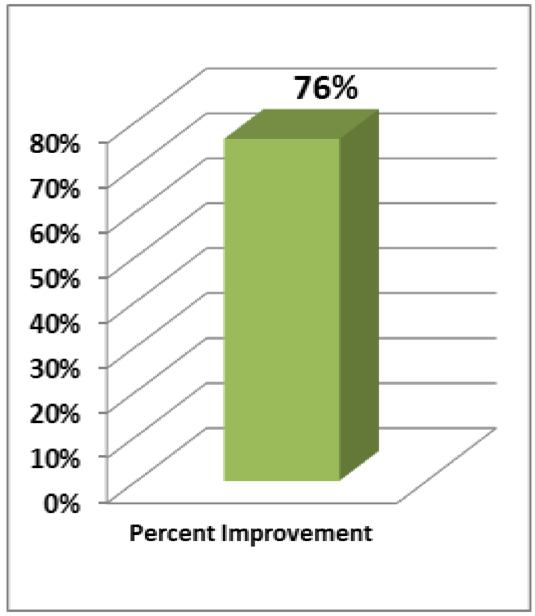


3. Manpower Requirements Comparison

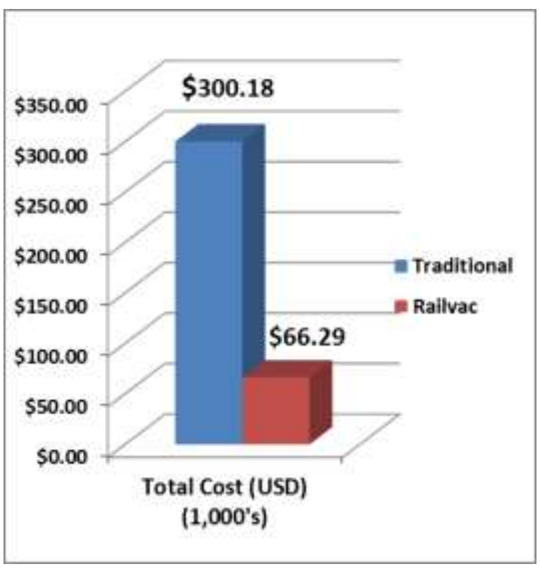
| | Traditional | Railvac | % Improvement Railvac vs. Traditional |
|---|---|---|---|
| Number of Employees | 50 | 12 | 76% |

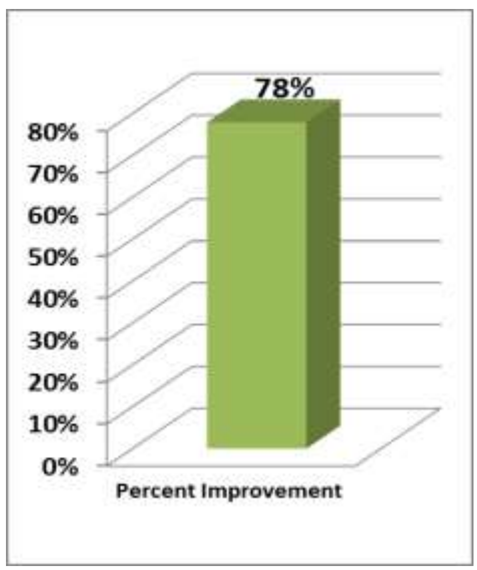



4. Total Cost Comparison

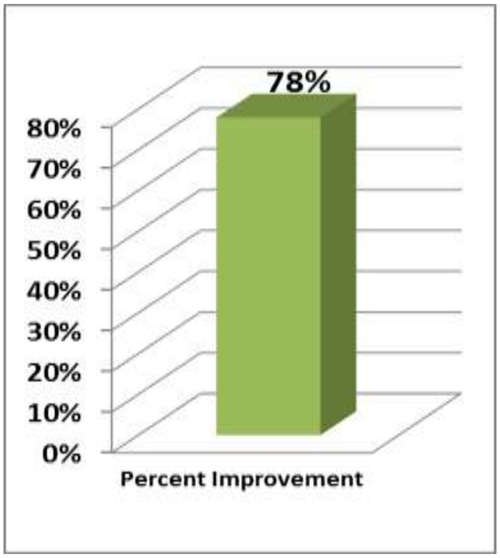
| | Traditional | Railvac | % Improvement Railvac vs. Traditional |
|---|---|---|---|
| Total Cost (USD) (1,000's) | $300.18 | $66.29 | 78% |



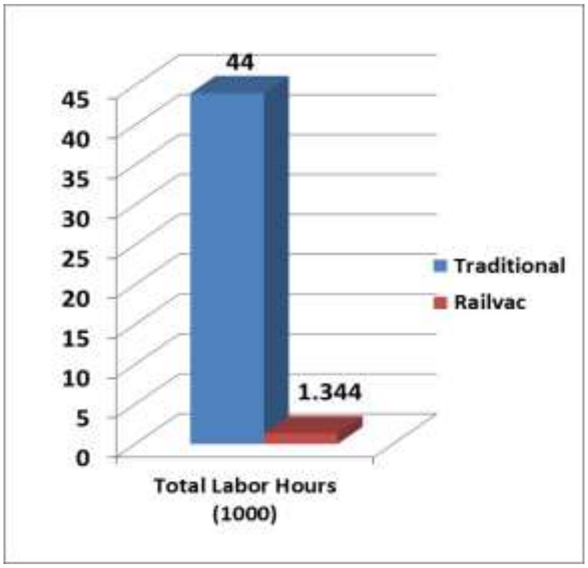
5. Unit Cost Comparison

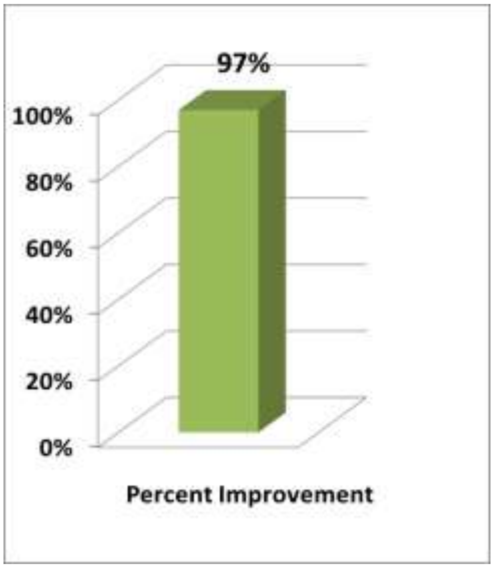
| | Traditional | Railvac | % Improvement Railvac vs. Traditional |
|---|---|---|---|
| Unit Cost ($ USD/Meter) | $134.43 | $29.69 | 78% |

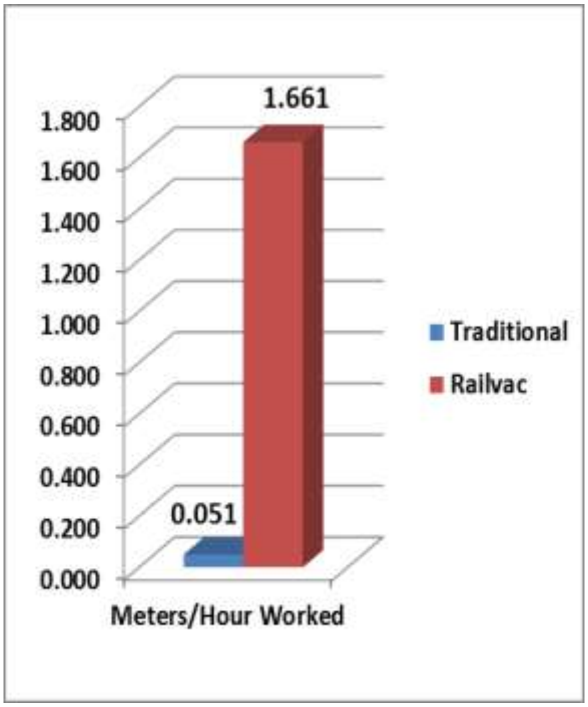

6. Total Labor Hours Worked Comparison

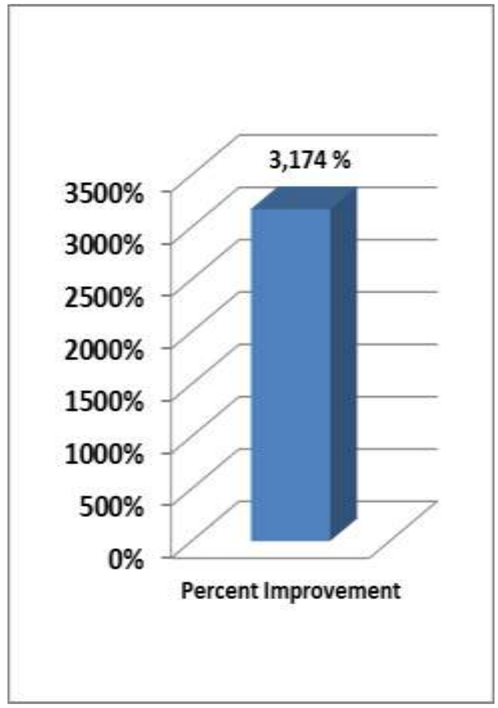
| | Traditional | Railvac | % Improvement Railvac vs. Traditional |
|---|---|---|---|
| Total Labor Hours (1000) | 44 | 1.344 | 97% |



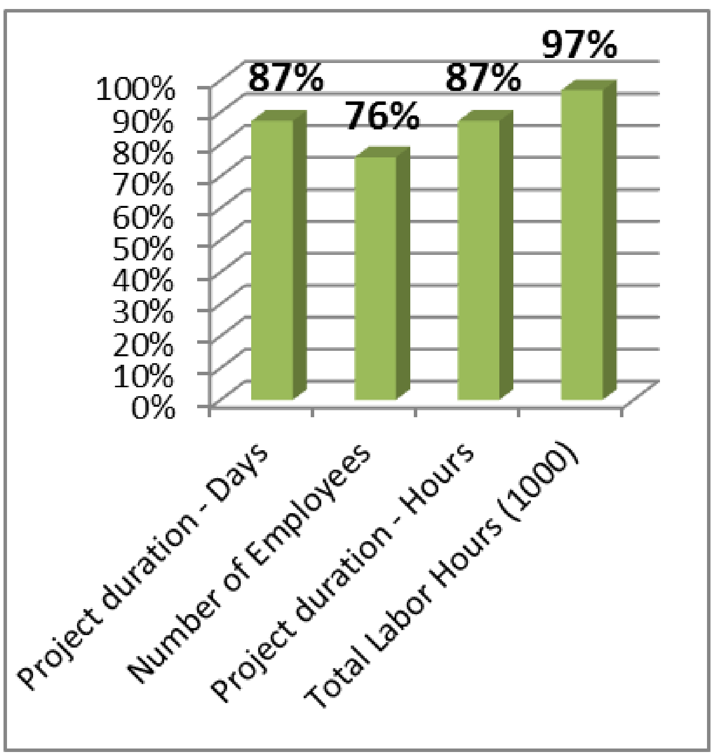



7. Productivity Comparison




8. Summary of Comparisons Improvements



## 9. Railvac Production Data (March 26, 2013 to March 26, 2014)

**PRODUÇÃO RAILVAC LRV-15**
**2013**

| Week | Year | Days | Range | Responsible coordination | Volume ($m^3$) | While producing liquid (h) | Average produced ($m^3$/h) | Observações |
|---|---|---|---|---|---|---|---|---|
| 10 | 2013 | 26-Mar | Elisson a Mario Belo | Barra do Piraí | 39 | 2:14 | 17.46 | Linha 1 - 69+700 (ombros e grade) |
| 10 | 2013 | 28-Mar | Elisson a Mario Belo | Barra do Piraí | 39 | 2:09 | 18.14 | Linha 1 - 70+200 (ombro esquerdo) |
| 11 | 2013 | 2-Apr | Elisson a Mario Belo | Barra do Piraí | 42.5 | 1:28 | 28.98 | Linha 1 - 69+400 (excesso de pedra entre via) |
| 11 | 2013 | 4-Apr | Elisson a Mario Belo | Barra do Piraí | 59.5 | 1:47 | 33.36 | Linha 1 - 70+150 (excesso de pedra entre via) |
| 12 | 2013 | 8-Apr | Elisson a Mario Belo | Barra do Piraí | 93.5 | 3:36 | 25.97 | Linha 1 - 71 +450 ao 71 +590 (excesso de pedra ombro) |
| 12 | 2013 | 9-Apr | Mario Belo a Gurgel | Barra do Piraí | 34 | 2:43 | 12.52 | Linha 1 - 76+400 |
| 12 | 2013 | 11-Apr | Mario Belo a Gurgel | Barra do Piraí | 76.5 | 3:21 | 22.84 | Bolsão 75+900 / 76+000 / 76+080 |
| 12 | 2013 | 12-Apr | Mario Belo a Gurgel | Barra do Piraí | 51 | 2:04 | 24.68 | Entre via superior túnel nº2 e ombro esquerdo 74+700 |
| 13 | 2013 | 18-Apr | Mario Belo a Gurgel | Barra do Piraí | 54 | 2:12 | 24.55 | 74+250 (entre via) 74+830 (ombro esq. e entre via) |
| 13 | 2013 | 19-Apr | Mario Belo a Gurgel | Barra do Piraí | 41 | 1:59 | 20.67 | 74+520 (Ombro esq.) 74+850 (entre via) |
| 14 | 2013 | 22-Apr | Mario Belo a Gurgel | Barra do Piraí | 39 | 1:49 | 21.47 | 74+470 (grade) |
| 14 | 2013 | 23-Apr | Mario Belo a Gurgel | Barra do Piraí | 51 | 3:17 | 15.53 | 74+830 (grade) 74+600 (entre via) |
| 14 | 2013 | 25-Apr | Mario Belo a Gurgel | Barra do Piraí | 73 | 2:44 | 26.71 | 72+910 (ombro e entre via) 72+800 (entre via) |
| 14 | 2013 | 26-Apr | Mario Belo a Gurgel | Barra do Piraí | 30 | 1:41 | 17.82 | Linha 1, 72+700 |
| 15 | 2013 | 29-Apr | Pátio da Barra | Barra do Piraí | 51 | 2:54 | 17.59 | Linha 1, 108+605 (Ombro esquerdo) |
| 15 | 2013 | 30-Apr | Pátio da Barra | Barra do Piraí | 104 | 4:19 | 24.09 | Linha 1, 108+300 / 107+500 |
| 15 | 2013 | 1-May | Pátio da Barra | Barra do Piraí | 42.5 | 1:44 | 24.52 | Linha 1, 106 e 107 |
| 16 | 2013 | 7-May | Pátio da Barra | Barra do Piraí | 91 | 3:10 | 28.74 | Linha 1, 106 e 107 |
| 16 | 2013 | 8-May | Pátio da Barra | Barra do Piraí | 73.5 | 2:51 | 25.79 | Linha 1, 106+850 |
| 16 | 2013 | 9-May | Pátio da Barra | Barra do Piraí | 43 | 3:37 | 11.89 | Linha 1, 104+500 a 104+100 |
| 16 | 2013 | 10-May | Pátio da Barra | Barra do Piraí | 102 | 3:56 | 25.93 | Linha 1, 107+100 a 107+700 |
| 17 | 2013 | 14-May | Bom Jardim | P2-06 | 21 | 1:29 | 14.16 | Pátio P2-6 linha 1 (16 m desguarnecendo total 99+544 ao 560) |
| 17 | 2013 | 15-May | Bom Jardim | P2-06 | 56 | 3:02 | 18.46 | Pátio P2-6 linha 2 (30m desguarnecendo total 99+530 ao 560) |
| 18 | 2013 | 21-May | Bom Jardim | P2-06 | 34.5 | 1:38 | 21.12 | Túnel dos cabritos, lado superior (104+300 - Ombro esquerdo) 132m |
| 18 | 2013 | 23-May | Bom Jardim | P2-06 | 34 | 2:22 | 14.37 | Túnel dos cabritos, lado superior (104+300 - centro da grade) 128m |
| 19 | 2013 | 27-May | Pátio da Barra | Barra do Piraí | 13 | 0:38 | 20.53 | Linha 1 Pátio da Barra(27m ombro esquerdo km107 +725 ao 751) |
| 19 | 2013 | 28-May | Pátio da Barra | Barra do Piraí | 39 | 2:23 | 16.36 | Linha 1 Pátio da Barra (km 107+600 ao 107 +700) |
| 19 | 2013 | 29-May | Pátio da Barra | Barra do Piraí | 52 | 2:09 | 24.19 | Linha 1 Pátio da Barra (entre km 107 e 108) |
| 20 | 2013 | 3-Jun | Paulo de Frontin | Barra do Piraí | 41.5 | 2:24 | 17.29 | Túnel 12 linha 1 (Excesso de pedra 411m linear) |
| 20 | 2013 | 4-Jun | Paulo de Frontin | Barra do Piraí | 26 | 1:13 | 21.37 | Linha 1 Pátio de Frontin |
| 20 | 2013 | 5-Jun | Pátio da Barra | Barra do Piraí | 65 | 2:50 | 22.94 | Linha 1 Pátio da Barra (excesso de pedra 167 m linear km 108 + 050 ao 217) |
| 20 | 2013 | 6-Jun | Pátio da Barra | Barra do Piraí | 77.5 | 3:57 | 19.62 | Linha 1 Pátio da Barra ( excesso de pedra 200m Entre via e ombro esq. km107 +500 ao 700) |
| 20 | 2013 | 7-Jun | Paulo de Frontin | Barra do Piraí | 26 | 1:18 | 20.00 | Linha 1 Pátio de Frontin ( 75m linear entre km 85 e 86) |
| 21 | 2013 | 11-Jun | Pátio da Barra | Barra do Piraí | 21.5 | 1:14 | 17.43 | Linha 1 Pátio da Barra (excesso de pedra) |
| 21 | 2013 | 12-Jun | Pátio da Barra | Barra do Piraí | 25.5 | 1:07 | 22.84 | Linha 1 Pátio da Barra (excesso de pedra) |
| 21 | 2013 | 14-Jun | Pátio da Barra | Barra do Piraí | 30.5 | 1:36 | 19.06 | Linha 1 Pátio da Barra (excesso de pedra 40 m linear) |
| 22 | 2013 | 19-Jun | Pátio da Barra | Barra do Piraí | 82.5 | 3:44 | 22.10 | Linha 1 Pátio da Barra (excesso de pedra km 107+450 ao 600)) |
| 22 | 2013 | 20-Jun | Pátio da Barra | Barra do Piraí | 69 | 2:38 | 26.20 | Linha 1 Pátio da Barra (excesso de pedra km 107+450 ao 600)) |
| 22 | 2013 | 21-Jun | Pátio da Barra | Barra do Piraí | 28 | 1:48 | 15.56 | Linha 1 Pátio da Barra (excesso de pedra km 106 + 400) |
| 23 | 2013 | 25-Jun | Pátio da Barra | Barra do Piraí | 34.5 | 1:17 | 26.88 | Linha 1 Pátio da Barra (excesso de pedra km 106 +450 ao 500) |
| 23 | 2013 | 26-Jun | Helisson a Gurgel | Barra do Piraí | 13 | 0:39 | 20.00 | Túnel #2 Linha 1, com descarga do material próximo ao túnel #3 |
| 23 | 2013 | 27-Jun | Frontin a Humberto | Barra do Piraí | 39.5 | 2:17 | 17.30 | Túnel #12, linha 2 300m de linha na inferior do túnel |
| 24 | 2013 | 1-Jul | Frontin a Humberto | Barra do Piraí | 38.5 | 2:34 | 15.00 | Túnel #12, linha 2, 400m linear (Descobrindo pregação) |
| 24 | 2013 | 2-Jul | Frontin a Humberto | Barra do Piraí | 29 | 1:46 | 16.42 | Túnel #12, linha 2, 200m lilnear (Descobrindo pregação) |
| 24 | 2013 | 3-Jul | Elisson a Mario Belo | Barra do Piraí | 48.5 | 2:23 | 20.35 | Km 68 +450 a 575 (Desguarnecendo valeta linha 1) |
| 24 | 2013 | 4-Jul | Frontin a Humberto | Barra do Piraí | 25.5 | 1:27 | 17.59 | Túnel #12, linha 2, 100m linear (Descobrindo pregação) |
| 25 | 2013 | 8-Jul | Elisson a Gurgel | Barra do Piraí | 26 | 1:19 | 19.75 | Excesso de pedra no desvio do pátio, e Linha 1 - Km 70 + 450 |
| 25 | 2013 | 9-Jul | Frontin a Humberto | Barra do Piraí | 22 | 1:28 | 15.00 | Túnel #12, linha 2, Desguarnecendo bolsão no suspiro do túnel |
| 26 | 2013 | 16-Jul | Helisson a Mario Belo | Barra do Piraí | 17 | 1:05 | 15.69 | Linha 2, Túnel #2 |
| 30 | 2013 | 13-Aug | Helisson a Mario Belo | Barra do Piraí | 17.5 | 0:44 | 23.86 | superior do túnel #1 (Remoção de excesso de pedra para posicionamento de trilho para troca). |
| 30 | 2013 | 14-Aug | Santana a Morsing | Barra do Piraí | 4.5 | 0:16 | 16.88 | Intervalo linha 2 (esgotamento de 3 bolsões na linha 1 próximo a PN Santana. |
| 30 | 2013 | 15-Aug | Morsing a Martins | Barra do Piraí | 21.5 | 1:25 | 15.18 | Desguarnecimento total de bolsão no km 97+ 710 a 730 na superior do túnel. |
| 31 | 2013 | 20-Aug | Helisson a Mario Belo | Barra do Piraí | 26.5 | 1:27 | 18.28 | , Esgotando bolsão (ombro até a base do dormente), Km 70 +300 a 328 e Km70 + 250 a 279. Limpando canaleta km 70 + 250 a 291. |
| 31 | 2013 | 21-Aug | Frontin a Humberto | Barra do Piraí | 21.5 | 0:53 | 24.34 | Trabalho túnel 12 linha 1, produção de 10m linear de bolsão |
| 31 | 2013 | 22-Aug | Palmeira a Mario Belo | Barra do Piraí | 26.5 | 1:12 | 22.08 | Túnel 7 , linha 2, lado superior, bolsão |
| 32 | 2013 | 26-Aug | Mario Belo a Gurgel | Barra do Piraí | 21.5 | 0:55 | 23.45 | Linha 1 - Túnel #3, 3 bolsões, km 76+630, 640 e 670 |
| 32 | 2013 | 27-Aug | Palmeira a Humberto | Barra do Piraí | 25.5 | 1:46 | 14.43 | Linha 2 - Túnel #12, bolsão sob chaft + valeta na superior do túnel |
| 32 | 2013 | 28-Aug | Palmeira a Humberto | Barra do Piraí | 17 | 0:38 | 26.84 | Linha 1, Inferior túnel 8 (Km 82+280), bolsão 10 metros |
| 32 | 2013 | 29-Aug | Gurgel a Palmeira | Barra do Piraí | 17 | 1:30 | 11.33 | Linha 2, Túnel #7 - Bolsão 9m linear + valeta na entre-via para escoar água |
| 33 | 2013 | 4-Sep | Humberto a Martins | Barra do Piraí | 51.5 | 2:08 | 24.14 | Linha 2, Desguarnecendo entre-via para escoar água de bolsão, km 91+800 a 92+000 |
| 33 | 2013 | 5-Sep | Palmeira a Frontin | Barra do Piraí | 30.5 | 1:44 | 17.60 | Linha 1 Túnel 11 e km 83 e linha 2 Túnel 11 |
| 35 | 2013 | 20-Sep | Pires a P1-05 | P1-07 | 39 | 1:51 | 21.08 | Túnel 75, km 324+563 ao 325+106, desguarnecimento ombro esquerdo 208 metros |
| 36 | 2013 | 25-Sep | Pires a P1-05 | P1-07 | 34 | 1:27 | 23.45 | Túnel 75, km 324+563 ao 325+106, desguarnecimento ombro esquerdo 64 metros |
| 36 | 2013 | 27-Sep | Pires a P1-05 | P1-07 | 26 | 1:13 | 21.37 | Túnel 75, km 324+563 ao 325+106, desguarnecimento ombro esquerdo 151 metros |
| 37 | 2013 | 3-Oct | P1-08 | P1-07 | 13 | 0:38 | 20.53 | Túnel 68, km278, desguarnecimento de entre-via para escoamento de bolsão 18m |
| 38 | 2013 | 9-Oct | Pires a P1-05 | P1-07 | 38 | 1:27 | 26.21 | Túnel 75, km 324+563 ao 325+106, desguarnecimento ombro esquerdo 120 metros |
| 38 | 2013 | 10-Oct | P1-08 | P1-07 | 43 | 2:15 | 19.11 | Túnel 68, km278, desguarnecimento de ombro direito e excesso de pedra. |
| 38 | 2013 | 11-Oct | Pires a P1-05 | P1-07 | 81.5 | 3:17 | 24.82 | Túnel 75, km 324+563 ao 325+106, desguarnecimento ombro direito 235metros e 20 casas para troca de dormente. |
| 39 | 2013 | 14-Oct | Pires a P1-05 | P1-07 | 8.5 | 0:20 | 25.50 | Túnel 75, km 324+563 ao 325+106, desguarnecimento ombro direito 31 metros |
| 39 | 2013 | 17-Oct | P1-08 | P1-07 | 26 | 0:54 | 28.89 | Viaduto 81, 15 metros de ombro esq. e dir. e viaduto 82, 17 metros de ombro esq. e dir. |
| 39 | 2013 | 18-Oct | Pires a P1-05 | P1-07 | 86 | 3:02 | 28.35 | Túnel 75, desguarnecimento 245 m linear e 30 casas para troca de dormentes |
| 41 | 2013 | 30-Oct | P2-06 ao P2-07 | P2-06 | 41 | 1:28 | 27.95 | Tunelão, 67 metros linear ombro direito |
| 41 | 2013 | 31-Oct | P2-06 ao P2-07 | P2-06 | 51 | 1:48 | 28.33 | Tunelão, 79 metros linear ombro direito |
| 42 | 2013 | 5-Nov | P2-06 ao P2-07 | P2-06 | 64.5 | 1:54 | 33.95 | Tunelão, 106 metros linear ombro direito |
| 42 | 2013 | 6-Nov | P2-06 ao P2-07 | P2-06 | 17 | 0:45 | 22.67 | Tunelão, 64 metros de canaleta lateral direita |
| 42 | 2013 | 7-Nov | P2-06 ao P2-07 | P2-06 | 38.5 | 1:24 | 27.50 | Tunelão, 64m linear de canaleta direita, 47m linear de canaleta esquerda. |
| 43 | 2013 | 12-Nov | P2-06 ao P2-07 | P2-06 | 72.5 | 2:19 | 31.29 | Tunelão, 115m linear ombro esquerdo |
| 43 | 2013 | 14-Nov | P2-06 ao P2-07 | P2-06 | 34 | 1:18 | 26.15 | Tunelão, 54m linear ombro esquerdo |
| 44 | 2013 | 19-Nov | P2-06 ao P2-07 | P2-06 | 34 | 1:09 | 29.57 | Tunelão, 53m linear ombro esquerdo |
| 44 | 2013 | 21-Nov | P2-06 ao P2-07 | P2-06 | 42.5 | 1:10 | 36.43 | Tunelão, 62m linear ombro direito e 23m linear ombro esquerdo |
| 45 | 2013 | 26-Nov | P2-06 ao P2-07 | P2-06 | 51 | 1:16 | 40.26 | Tunelão, 127 metros linear ombro direito |
| 45 | 2013 | 28-Nov | P2-06 ao P2-07 | P2-06 | 70 | 2:02 | 34.43 | Tunelão, 87m linear de excesso de pedras e canaleta lado direito |
| 46 | 2013 | 3-Dec | P2-06 ao P2-07 | P2-06 | 77 | 2:37 | 29.43 | Tunelão, 82m linear de excesso de pedras e canaleta lado direito |
| 46 | 2013 | 5-Dec | P2-06 ao P2-07 | P2-06 | 72.5 | 2:23 | 30.42 | Tunelão, 75m linear de excesso de pedras e canaleta lado direito |
| 47 | 2013 | 10-Dec | P2-06 ao P2-07 | P2-06 | 51 | 1:33 | 32.90 | Tunelão, 165m linear de excesso de pedras lado direito |
| 47 | 2013 | 11-Dec | P2-06 ao P2-07 | P2-06 | 76.5 | 2:37 | 29.24 | Tunelão, 123m linear de excesso de pedras lado direito |
| 47 | 2013 | 12-Dec | P2-06 ao P2-07 | P2-06 | 85 | 1:56 | 43.97 | Tunelão, 85m linear excesso de pedra na lateral direita e 42m lado direito e esquerdo (Sacos Bag) túnel 45. |
| 48 | 2013 | 17-Dec | P2-06 ao P2-07 | P2-06 | 42.5 | 1:53 | 22.57 | Tunelão, 154m linear de excesso de pedras lado esquerdo |
| 48 | 2013 | 19-Dec | P2-06 ao P2-07 | P2-06 | 17 | 1:06 | 15.45 | Tunelão, 65m linear, material retirado da canaleta pela equipe da infra |
| 2 | 2014 | 7-Jan | IPG e IBA | IPG | 85 | 1:40 | 51.00 | Túnel entre IPG e IBA. Desg. de 125 m linear de ombros esquerdo e direito. |
| 2 | 2014 | 8-Jan | IPG e IBA | IPG | 153 | 2:32 | 60.39 | Túnel entra IPG e IBA, Desg. de 110 m linear de ombros esq. e 155m de ombro direito |
| 2 | 2014 | 9-Jan | IPG e IBA | IPG | 102 | 1:36 | 63.75 | Túnel entre IPG e IBA, Desg. de 120 m linear de ombro direito e 105m linear de ombro esq. |
| 3 | 2014 | 13-Jan | IPG e IBA | IPG | 100 | 1:31 | 65.93 | Túnel entre IPG e IBA, Desg. de 155m linear, ombro esquerdo. (km 4+975 ao 5+130) |
| 3 | 2014 | 14-Jan | IPG e IBA | IPG | 127.5 | 1:53 | 67.70 | Túnel entre IPG e IBA, Desg. de 155 m linear de ombro esquerdo. (5+130 ao 5+285) |
| 3 | 2014 | 15-Jan | IPG e IBA | IPG | 187 | 3:12 | 58.44 | Desg. de 325 m linear de ombro esq. e 10m linear de ombro direito. (4+870 ao 4+545 e 4+545 ao 5+555) |
| 3 | 2014 | 16-Jan | IPG e IBA | IPG | 144.5 | 2:00 | 72.25 | Desguarnecimento de 220 m linear de ombro direito. (4+555 ao 4+775) |
| 3 | 2014 | 17-Jan | IPG e IBA | IPG | 137.5 | 2:01 | 68.18 | Desg. de 220 m linear de ombro direito. (4+775 ao 4+870, 5+050 ao 5+075, 5+285 ao 5+185) |
| 3 | 2014 | 18-Jan | IPG e IBA | IPG | 149.5 | 2:29 | 60.20 | Desg. de 190 m linear de ombro direito. (5+075 ao 5+205 e 4+370 ao 4+310) |
| 4 | 2014 | 20-Jan | IPG e IBA | IPG | 153 | 2:33 | 60.00 | Desg. de 170 m linear de ombro direito e esquerdo. (5+350 ao 5+510 e 4+310 ao 4+300) |
| 6 | 2014 | 5-Feb | P2-06 ao P2-07 | P2-06 | 34 | 2:10 | 15.69 | Tunelão, Desg. 277 m de lateral direita (96+684 ao 96+407) |
| 6 | 2014 | 6-Feb | P2-06 ao P2-07 | P2-06 | 30.5 | 1:26 | 21.28 | Desguarnecimento de 130 m linear lateral direita. (89+630 a 89+760) e 15m linear lateral esquerda (89+630 a 89+645) |
| 7 | 2014 | 10-Feb | P2-06 ao P2-07 | P2-06 | 42.5 | 2:33 | 16.67 | Desguernecimento de 380, linear nas laterais esquerda e direita. (km88,380 ao 88,760) |
| 7 | 2014 | 11-Feb | P2-06 ao P2-07 | P2-06 | 38.5 | 1:24 | 27.50 | Desguernecimento de 32m linear (sacos Bag) nas laterais esquerda e direita. |
| 7 | 2014 | 12-Feb | P2-06 ao P2-07 | P2-06 | 61.5 | 2:49 | 21.83 | Desguernecimento de 135m linear nas laterais esquerda e direita. |
| 7 | 2014 | 13-Feb | P2-06 ao P2-07 | P2-06 | 42.5 | 2:12 | 19.32 | Desguernecimento de 485m linear nas lateral direita, entre o km 91,940 e km 94,880. |
| 7 | 2014 | 14-Feb | P2-06 ao P2-07 | P2-06 | 47 | 2:25 | 19.45 | Desguernecimento de 530m linear na lateral direita, do km 95,180 ao 95,720. |
| 8 | 2014 | 18-Feb | P2-06 ao P2-07 | P2-06 | 51 | 2:19 | 22.01 | Desguernecimento de 390m linear na lateral direita, do km 95,720 ao 96,110. |
| 8 | 2014 | 19-Feb | P2-06 ao P2-07 | P2-06 | 51 | 2:33 | 20.00 | Desguernecimento de 440m linear na lateral direita, do km 96,110 ao 96,410 e 94,820 ao 94,960. |
| 8 | 2014 | 20-Feb | P2-06 ao P2-07 | P2-06 | 42.5 | 2:10 | 19.62 | Desguernecimento de 340m linear na lateral direita, do km 94,480 ao94,600 e 94,960 ao 95,180. |
| 9 | 2014 | 25-Feb | P2-06 ao P2-07 | P2-06 | 34 | 1:50 | 18.55 | Desguernecimento de 780m linear na lateral direita, do km 94,920 ao 94,140. |
| 9 | 2014 | 26-Feb | P2-06 ao P2-07 | P2-06 | 25.5 | 0:58 | 26.38 | Desguernecimento de 260m linear na lateral direita, do km 94,140 ao 93,880. |
| 9 | 2014 | 27-Feb | P2-06 ao P2-07 | P2-06 | 34 | 2:07 | 16.06 | Desguernecimento de 350m linear na lateral direita, do km 92,600 ao 92,950 e 1950m linear na lateral esquerda do km89,600ao 91,550. |
| 9 | 2014 | 28-Feb | P2-06 ao P2-07 | P2-06 | 34 | 1:40 | 20.40 | Desguernecimento de 610 m linear na lateral direita, do km 94,330 ao 94,140 e 94,030 ao 93,610. |
| 10 | 2014 | 6-Mar | P2-06 ao P2-07 | P2-06 | 55.5 | 2:40 | 20.81 | Desguernecimento de 810m linear na lateral direita, do km 92,800 ao 93,610. |
| 10 | 2014 | 7-Mar | P2-06 ao P2-07 | P2-06 | 8.5 | 0:44 | 11.59 | Desguernecimento de 240m linear na lateral direita, do km 92,800 ao 92,560. |
| 11 | 2014 | 11-Mar | P2-06 ao P2-07 | P2-06 | 34 | 1:38 | 20.82 | Desguernecimento de 1370m linear na lateral direita, do km 92,560 ao 91,900 e do 90,050 ao 90,760 |
| 11 | 2014 | 12-Mar | P2-06 ao P2-07 | P2-06 | 34 | 2:03 | 16.59 | Desguernecimento de 980m linear na lateral esquerdo, do km 92,000 ao 92,980. |
| 11 | 2014 | 13-Mar | P2-06 ao P2-07 | P2-06 | 64 | 2:25 | 26.48 | Desguernecimento de 850m linear na lateral esquerdo, do km 92,980 ao 93,830. |
| 12 | 2014 | 17-Mar | P2-06 ao P2-07 | P2-06 | 55 | 2:03 | 26.83 | Desguernecimento de 970m linear na lateral direita, do km 93,830 ao 94,800. |
| 12 | 2014 | 18-Mar | P2-06 ao P2-07 | P2-06 | 51 | 1:49 | 28.07 | Desguarnecimento de 440m linear na lateral esquerdo , do km 94,800 ao95,240. |
| 12 | 2014 | 19-Mar | P2-06 ao P2-07 | P2-06 | 73 | 2:26 | 30.00 | Desguernecimento de 940 m linear na lateral esquerda, do km 95,240 ao 96,180. |
| 12 | 2014 | 20-Mar | P2-06 ao P2-07 | P2-06 | 55.5 | 1:29 | 37.42 | Desguernecimento de 560 m linear na lateral esquerda, do km 96,180 ao 96,740. |
| 13 | 2014 | 24-Mar | P2-06 ao P2-07 | P2-06 | 34 | 1:20 | 25.50 | Desguernecimento de 650m linear na lateral direita, do km 88+920 ao 89+570 |
| 13 | 2014 | 25-Mar | P2-06 ao P2-07 | P2-06 | 17 | 1:09 | 14.78 | Desguernecimento de 200m linear na lateral esquerda, do km 88+720 ao 88+920 |
| 13 | 2014 | 26-Mar | P2-07 ao P2-08 | P2-06 | 51 | 1:12 | 42.50 | Túnel 38, Desguernecimento de 85m linear na lateral esq. E dir., do km 80+870 ao 80+820 e 80+135 ao 80+100 |
| | | | | Total | 6319.5 | Average | 25.9 | |

# Appendix D

1. June 1, 2015; Km71+445 to 71+429

Before – June 1, 2015

After Ballast Excavation - June 1, 2015

2. June 2, 2015; km74 + 232 to 74 + 018

Before – June 2, 2015

After Ballast Excavation – June 2, 2015

3. Summary of June 1 – 2, 2015 Production

| Summary of MRS' June 1-2, 2015 Production | | | | | | |
|---|---|---|---|---|---|---|
| **Date** | **Hours Worked (Hrs)** | **Volume ($m^3$)** | **Average ($m^3$/Hr.)** | **Per Unit Cost (R$/$m^3$)** | **Per Unit Cost ($ USD/m3)*** | **Total Cost ($USD)*** |
| **1-Jun-15** | 1.82 | 39 | 21.43 | R$ 60.62 | $ 19.15 | $747.03 |
| **2-Jun-15** | 3.48 | 91 | 26.15 | R$ 60.62 | $ 19.15 | $1,743.07 |
| **Two Day Totals** | 5.3 | 130 | 24.53 | R$ 60.62 | $ 19.15 | $2,490.10 |

* NOTE: R$ 1 = $0.315978 USD Conversion Rate

# Appendix E

1. Pictures of Railvac Undercutting beside platform on Third Rail Track

Condition Before Undercutting

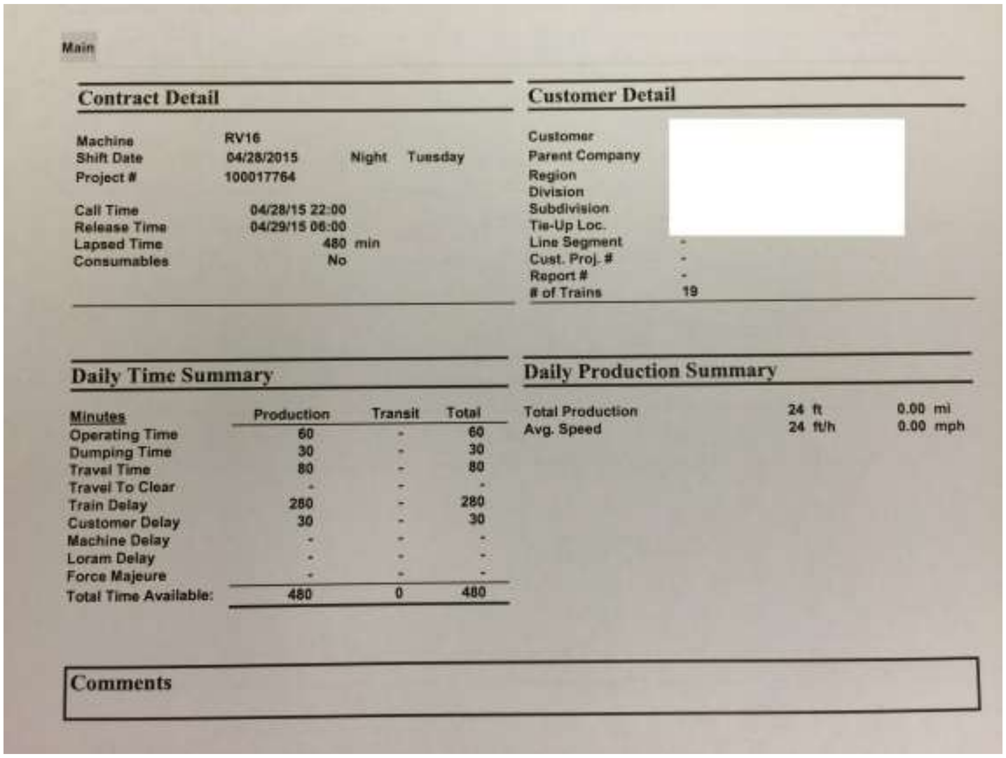
Railvac Undercutting-Notice Third Rail and Dropped Ties

Railvac Sliding Dropped Ties onto Right-of-Way Under Third Rail

Railvac Staging New Ties Under Rails for Installation

**New Ties Being Secured to Rails and Reattaching Third Rail**

**Track Waiting for Removal of Old Ties, New Ballast  and Tamping**



Main

## Contract Detail

| | | | |
|---|---|---|---|
| Machine | RV16 | | |
| Shift Date | 04/28/2015 | Night | Tuesday |
| Project # | 100017764 | | |
| Call Time | 04/28/15 22:00 | | |
| Release Time | 04/29/15 06:00 | | |
| Lapsed Time | 480 min | | |
| Consumables | No | | |

## Customer Detail

| | |
|---|---|
| Customer | |
| Parent Company | |
| Region | |
| Division | |
| Subdivision | |
| Tie-Up Loc. | |
| Line Segment | - |
| Cust. Proj. # | - |
| Report # | - |
| # of Trains | 19 |

## Daily Time Summary

| Minutes | Production | Transit | Total |
|---|---|---|---|
| Operating Time | 60 | - | 60 |
| Dumping Time | 30 | - | 30 |
| Travel Time | 80 | - | 80 |
| Travel To Clear | - | - | - |
| Train Delay | 280 | - | 280 |
| Customer Delay | 30 | - | 30 |
| Machine Delay | - | - | - |
| Loram Delay | - | - | - |
| Force Majeure | - | - | - |
| Total Time Available: | 480 | 0 | 480 |

## Daily Production Summary

| | | |
|---|---|---|
| Total Production | 24 ft | 0.00 mi |
| Avg. Speed | 24 ft/h | 0.00 mph |

## Comments

**Hard Copy Detail of Work Performed**

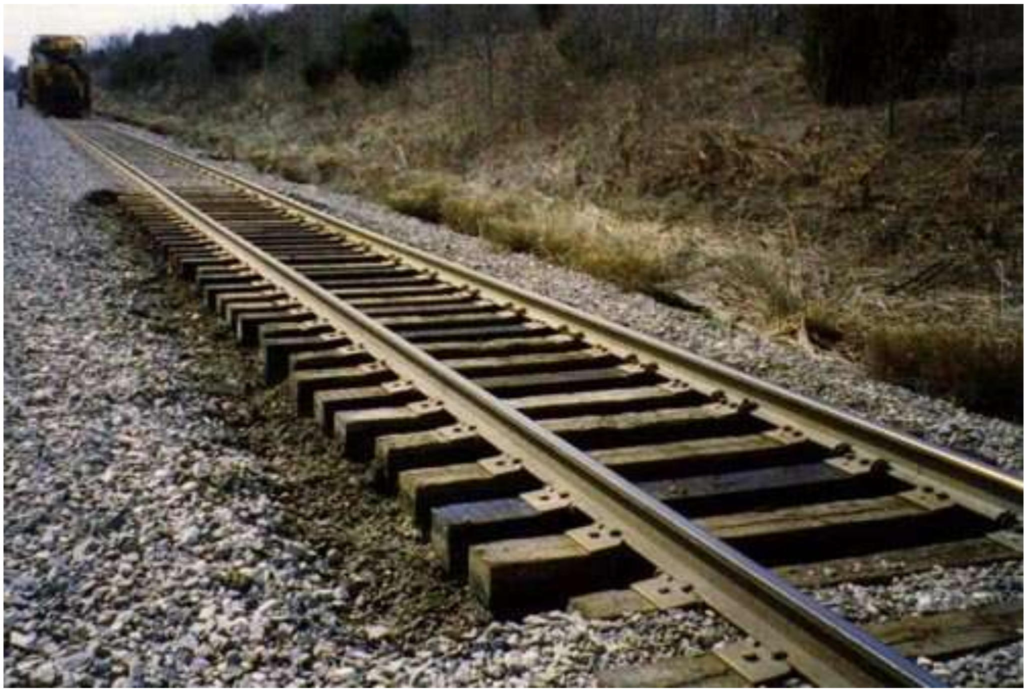
## Appendix E

Undercutting Bridge Deck

Bridge Deck Cleaning

Undercutting Switch and Turnout


Clean Up Taconite Pellets



Undercut Mud Spots – Open Track

## Bibliography

TTCI analysis of R-1 data; 20th Annual AAR Research Review, 2015

Kerr, D. A. (2003), *Fundamentals of Railway Track Engineering*. Omaha: Simmons Boardman Books

MRS Logistica Railways

Canadian National Railways

Loram Maintenance of Way

## Biographies:

**Tom Bourgonje, Chief Engineer Western Region Canadian National Railway,** has over 30 years of experience working for CN starting out as a machine helper working on a brush cutter in 1980. Since that first job Tom has worked throughout CN's system in both transportation and engineering. From that first job as machine helper Tom progressed through the ranks from mechanic to surveying for construction projects to assisting CN's Chief Engineer of Projects. After 15 or so years in engineering, Tom moved into CN's transportation department as General Manager of the Prairie Division and then General Manager of Prince George. In 2008, Tom rejoined the engineering department in his current role as Chief Engineer Western Region. Tom holds a Bachelor of Civil Engineering degree from Lakehead University as well as a Civil Technology degree. Tom's education and varied background enable him to look at track infrastructure issues from multiple viewpoints to create the most beneficial solution for all parties involved.

**Scott Diercks, Director of Marketing and Business Development at Loram Maintenance of Way**, has more than 20 years of progressively responsible experience at Loram. Scott vast experience with Loram spans various departments and roles with special emphasis on contract operations, product development, marketing and sales, and various special projects. Scott's understanding of the rail industry and its challenges both domestically and internationally, equipment design and operation, and experience in operational challenges have proven instrumental in developing new products and improving existing product lines. Scott has a Bachelor in Business Administration from the College of St. Scholastica and is pursuing his MBA at St. Cloud State University (2016 expected). Scott is a member of American Society of Civil Engineers (ASCE), American Railway Engineering and Maintenance of Way Association (AREMA), and holds a certification in Lean Product Development.

**John Simmons, Marketing Specialist – New Product Development, Loram Maintenance of Way**, has over 30 years of experience in heavy equipment engineering and manufacturing. John has work 14 years with Loram as a Project Engineer, Quality Engineer and in New Product Development. John has a Bachelor of Mechanical Engineering degree from South Dakota State University and is a Certified Quality Engineer.

**Fernando Silva, Senior Track Maintenance and Engineering Consultant**

**Marc Hackett, Director, Ballast & Road Bed Maintenance, Loram Maintenance of Way**,