ISSUES AND CHALLENGES WITH LOGISTICS OF RAIL MAINTENANCE

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ABSTRACT

Detection and rectification of rail defects are major issues for all rail players around the world. Some of the defects include worn out rails, weld problems, internal defects, corrugations and rolling contact fatigue (RCF) initiated problems such as surface cracks, head checks, squats, spalling and shelling. If undetected and/or untreated these can lead to rail breaks and derailments. There are challenges to the infrastructure maintenance people with logistics for effective inspection and cost effective rectification decisions. If these issues are addressed properly then inspection and rectification decisions can reduce potential risk of rail breaks and derailments. Inspite of continuous efforts by all rail operators around the world to reduce costs, a substantial amount of railway budget is spent on inspection and maintenance of rails. These costs are further increased by inaccurate logistics decisions related to maintenance and inspection personnel, equipment, and planning. This paper addresses the issues and challenges related to logistics of rail maintenance with an aim to reduce costs and risk related to rail operations.

Keywords: *Rail Inspection, Rail Maintenance, Logistics, Cost, Risk.*

1. INTRODUCTION

Detection and rectification of rail defects are major issues for all rail players around the world. These defects include worn out rails, weld joint problems, internal defects, corrugations and rolling contact fatigue (RCF) initiated problems such as surface cracks, head checks, squats, spalling and shelling. If undetected and/or untreated these can lead to rail breaks and derailments.

In this paper, issues related to rail maintenance, the risk and cost and the challenges in current scenario are discussed. Section 1 introduces an overview of rail defects. Section 2 focuses on the main issues related to risk and cost based rail inspection and maintenance procedures. Section 3 describes use of logistics as a tool for risk and cost reduction and the challenges in front of rail players. The concluding section discusses summary and scope for future work.

2. ISSUES RELATED TO RAIL MAINTENANCE

Some of the defects found in rails are listed in Tables 1 and 2.

Table 1: Causes of defective Rails (Sawley and Reiff, 2000)

Railway	First	Second	Third	Fourth
Rail track (99/00)	Squats 21.7%	Vertical/transverse 20.1%	Horiz./longitudinal 12.5%	Bolt holes 9.6%
SNCF (1999)	Squats 23.4%	Internal fatigue 11.5%	Shells 8.4%	Thermite welds 4.7%
HSPC (1999)	Thermite welds 31.5%	Wheel burns 17.2%	Horizontal split webs 13.3%	Bolt holes 11.3%
NS (1997)	Insulated Joints 59.4%	Transverse defects 18%	Thermite welds 15%	Fatigue Failure 5.2%
DB (1996)	Thermite welds 29%	Sudden fracture 18%	Fatigue Failure 16%	Electric bonds 4%
Banverket* (1998)	Transverse fracture 55.1%	Welded joint 32.7%	Horizontal defect 6.1%	Vertical split 2.0%
HH1 (1999)	Vertical split heads 34.7%	Thermite welds 20.3%	Detail fractures 13.1%	Bolt holes 12.2%
HH2 (1999)	Transverse defects 23.6%	Thermite welds 15.5%	Wheel burns 13.2%	Shells 9.6%

Table 2: Causes of Broken Rails (Sawley and Reiff, 2000)

Railway	First	Second	Third	Fourth
Rail track (99/2000)	Vertical/transverse 39.5%	Thermite welds 22.4%	Bolt holes 14.9%	Horiz./longitudinal 7.4%
SNCF (1999)	Thermite welds 35.3%	Internal fatigue 18.6%	Squats 8.8%	Rail manufacture 6.1%
Banverket* (1998)	Transverse fracture 44.1%	Vertical split 19.4%	Welded joint 19.4%	Horizontal defect 17.2%
HH2 (1999)	Transverse defects 37.9%	Thermite welds 35.6%	Bolt holes 5.8%	Flash welds 5.6%

Some of the issues related to inspection and maintenance are covered in the following section.

2.1 Rail Inspection

The effectiveness of rail inspection depends on the efficiency and accuracy of the inspecting equipments. It also depends on skills and experience of inspectors. Errors in inspection are important issues and its reduction is a big challenge. This mainly depends on the technological limitations of the inspection equipments and the skill level of the rail inspectors. Figure 1 shows the venn diagram of inspection and detection, rail breaks and derailments. The venn diagram shows the percentage of defect detected by different inspection procedures. By improving the inspection techniques and more efficient equipments, reduction in undetected defects and false detection is possible.

Many rail players follow in-house inspection; in this inspection process the skilled personnel as well as required equipments are company employed/owned. Outsourced inspection is also followed widely, in which the inspection process is outsourced to various ancillary companies. The advantages and disadvantages of inhousing and outsourcing are discussed in section 3.

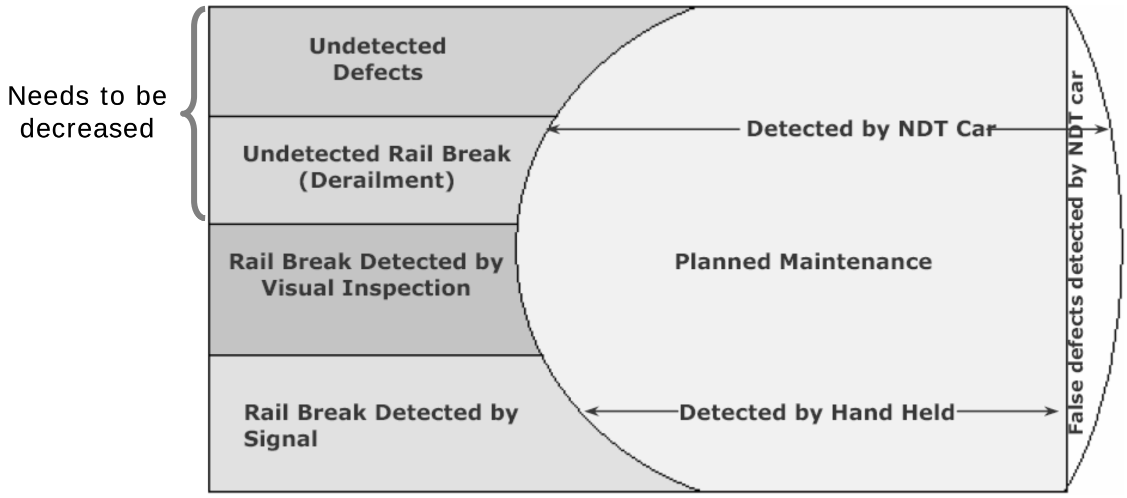

Figure 1. Venn diagram of inspection and detection, Rail breaks and derailment [Chattopadhyay, *et al*, 2005]

Inspection is also governed by weather conditions. In cold countries, inspection of rail becomes difficult and costly affair in winter. Another important issue is management of rail traffic during inspection. Some of the rail routes are so busy that it becomes very difficult to stop train traffic and do rail inspection and maintenance, in these routes rail inspection and maintenance is done during night time. The workers and inspectors have to be paid more for working during night hours. Still it is a challenge to effectively carry out inspection and maintenance procedures keeping optimal rail inspection and maintenance cost and minimal traffic disruption.

2.2 Rail Wear

Wear occurs due to interaction of rail and wheel. It includes abrasive wear and adhesive wear. Jendel, (1999) defined the concept of mild and severe wear. Mild wear takes place slowly but severe wear is often much faster, similar to adhesive wear. Severe wear is predominant in curves and dry conditions (Olofsson and Nilsson, 2002). Mild wear is observed at the wheel tread and rail crown, and severe wear is observed at the wheel flange and gauge face. Zakharov, (2001) classified wear mode in rails as mild, severe and catastrophic. The basis of this classification was characterized by different wear rate, surface and wear debris form and size. Wear debris in the size range of 1000 µm, 500 µm and 300 µm are categorized into mild, severe and catastrophic wear respectively.

Three commonly used techniques which are followed for rail-wheel lubrication are:

- Top of rail lubricators
- Wheel flange lubricators
- Wayside lubricators
- On board lubricators

In Sweden, about 3000 wayside lubricators are installed, and the total investment cost excluding the annual maintenance cost is about US $ 7.9 million (Waara, 2000). Railways around the world are spending such high cost for rail lubrication because if it is neglected, rail replacement would be the ultimate solution, which is far more costly. Lubrication helps to reduce rail gauge face wear and reduces energy or fuel consumption along with noise reduction.

However, excessive lubrication leaves residue behind that builds up on the rails and wheels, resulting in potential environmental hazards. Excessive lubrication also reduces friction more than required which increases the train's braking distance, this may build up risk in safe operation of trains. If we look on the other side, according to American Association of Railroads, 2 billion US$ are spent in excess on ineffective lubrication (Diamond and Wolf, 2002). The issue of effective lubrication of rails depends on the lubrication techniques used. Designing better and cost effective lubrication techniques and implementing them is a major challenge to the rail players around the world. In many of the wayside lubricators, optimum frequency of lubrication needs to be modeled based on detailed analysis so that it reduces derailment risk and rail/wheel damage and at the same time it is also cost effective. "Effective lubrication can only be enforced if adequate monitoring methods are available." (Peters and Reiff, 1989), thus the sensors to actuate the lubricators should also be sensitive enough to optimize lubrication frequency. Weather conditions are of particular concern to these lubricators. The applicator nozzles when not used for a long time in summer starts clogging; this leads to improper functioning of the lubrication system. This problem is frequently faced in many parts of Australia, where summers are hot. Lubricators need to be cleaned before the start of winter in cold countries like Sweden as well. This procedure is important as the nozzles of these lubricators may clog in winter due to no lubrication during winter. It takes two persons one and half to two hours in Sweden to clean up wayside lubricators. If it is done on the site then it costs US $ 360 /service (2 personnel x 2 hours and one car for transportation). If it is done at depot the cost could be different. The cost to maintain the lubricators cost around US $ 900 - US $ 1500 /year/apparatus (the lubricators are used only for six months as there is no lubrication during winter) this includes fill up and maintenance of lubricators (Chattopadhyay, *et al*, 2004). Biodegradable lubricants are also being used by various rail operators but the economic side of their implementation is still an issue. Cost effectiveness of lubricants is analysed by condition monitoring of lubricant properties and prediction of remaining useful life of the lubricant so that frequent oil change is avoided (Kumar *et al*, 2005).

2.3 Rolling Contact Fatigue (RCF)

In the late 1990s RCF defects accounted for about 60% of defects found by East Japan Railways, while in France (SNCF) and UK (Railtrack) the figures were about 25 and 15%, respectively. RCF is a major future concern as business demands for higher speed; higher axle loads, higher traffic density and higher tractive forces increase (see Cannon *et al*, 2003).

Analysis and modelling of RCF initiated defects have been done by many researchers, [see, Ringsberg and Bergkvist (2003), Ishida, *et al* (2003), Fletcher and Beynon (2000), Sawley and Kristan (2003) and Jeong (2003)] to find out ways to reduce the initiation and propagation of these defects. Lubrication reduces wear rate and damage to the rails but on the other hand it also causes fluid entrapment in cracks that leads to crack pressurization and reduces the crack face friction that allows relative shear of the crack faces. This accelerates crack propagation. Presence of manufacturing defect in rail subsurface and the direction of the crack mouth on the rail surface are both responsible for guiding crack development direction (see Bower and Johnson, 1991 and Bogdanski *et al*, 1997) Presence of water, snow or lubricant on the rails may increase crack propagation rate. When these minute head checks are filled with water or lubricants they don't dry up easily. During wheel rail contact, these liquids get trapped in the crack cavities and build up very high localized pressure which may even be greater than the compressive stress. If head checks are in the direction of train traffic, crack growth takes place due to liquid entrapment, but when head checks are in opposite direction of train traffic, the liquid is forced out before its entrapment.

Rail grinding removes surface metal from the rail head. Grinding is done by a series of rotary abrasive grinding stones mounted at different angles on a rail car to give the rail head its required profile. It is done mainly with intensions to control RCF defects and rail wear. Rail grinding became increasingly recognized for controlling RCF defects from 1980 onwards, prior to that it was mainly focused on corrugation removal. At that time barely 15% of Canadian Pacific Railway's (CPR) grinding budget was devoted to treatment of RCF compared to 60% on control of corrugation. In the late 1990s, grinding as a treatment of RCF of rails became a more established approach and began to be adopted on some European railways. It is now widely followed in Europe. The annual grinding budget in North America for larger railways is about US $ 500 per kilometer of track, this means that on a system with 20 000 km of track, the grinding budget is about US $ 10 million. This figure includes all costs associated with grinding (Cannon *et al*, 2003).

Rail grinding has two approaches, corrective and preventive grinding. Corrective grinding requires deep and infrequent cuts where as preventive grinding requires thin but more frequent cuts (Kalousek, *et al*, 1989). Generally the minimum interval for rail grinding is in the range 10–15 million gross tones (MGT). The Swedish national rail administration, Banverket follows preventive grinding on new rails within one year or after 5 MGT of traffic load. Later on regrinding is done in a cyclic manner called maintenance grinding, when grinding is done specifically to remove severe irregularities or defects in certain areas of the rail section, it is termed as corrective grinding according to Banverket. But the issue of having optimal grinding frequency depending on weather conditions is still a challenge for rail players.

2.4 Rail Welding

Small imperfection in welds can cause cracks to initiate. A defect free weld requires skilled workforce, better weld material and better welding techniques along with better welding equipments. In Sweden inspection, welding and rectification process becomes a costly affair due to snow and ice in winters. Most of the defects which do not pose immediate risk of damage to rail assets or derailment risk are deferred till the end of winter.

Rail players are always in difficulties to decide between outsourced maintenance or in-house maintenance, depending upon the capability, cost effectiveness, skill availability, availability of equipments and technology. Risk and cost are analyzed by rail infrastructure operators in maintenance decisions. It covers rail lubrication, rail grinding and rail weld. Other important issues are:

- Rail material
- Rail traffic density and axle load
- Track geometry

2.5 Rail Rectification and Replacement

Safety and integrity of rail sections are maintained by rail rectification, replacement and rerailing. Rail rectification is done where minimal repair is required, this may be in the form of small rail section replacement less than 110 meters of rail, rail welding and fastening of fish plates where required. If the rail is replaced for rail length greater than 110 meters then it is known as rail replacement. Major overhauling of rails, is known as rerailing.

Rail replacement is based on a number of responsible factors. Even now, rails are often replaced based on their life or MGT. Finding out optimal rail replacement interval which is an issue for rail players. This also depends on the wear limit and fatigue. Weather condition is also an important factor. In cold countries like Sweden, rail replacement and rerailing could only be done in summers.

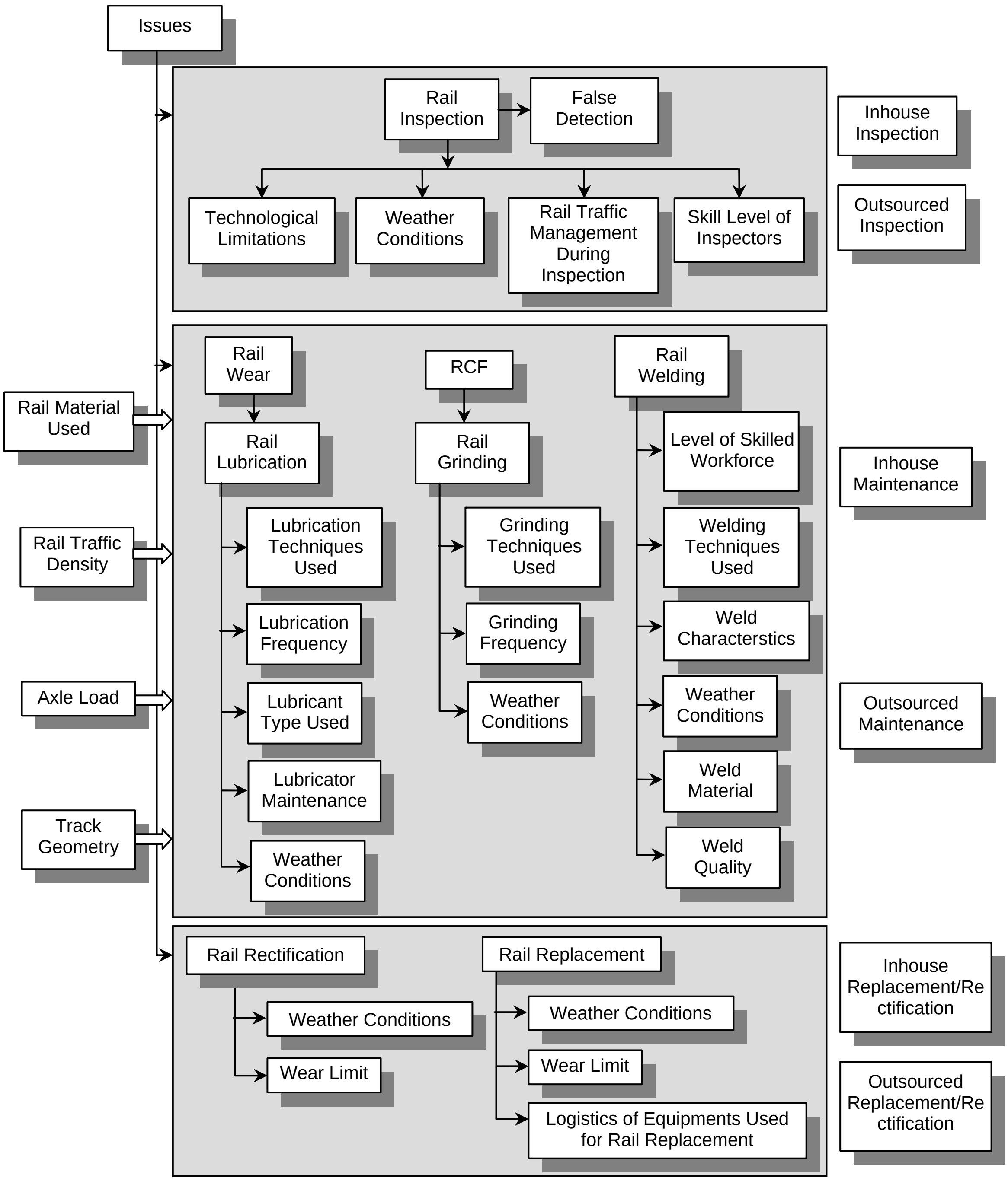

Figure 2. Issues related to rail maintenance

These issues are captured in Figure 2 for detail analysis of challenges for cost effective decisions in logistics planning related to rail track maintenance.

3. CHALLENGES WITH RAIL INFRASTRUCTURE OPERATORS

Logistics of Rail Maintenance is a big challenge for rail players. Reliability and availability of the equipment, capability of equipment, availability of skilled personnel and rail track are essential to meet these challenges and are shown in Figure 3.

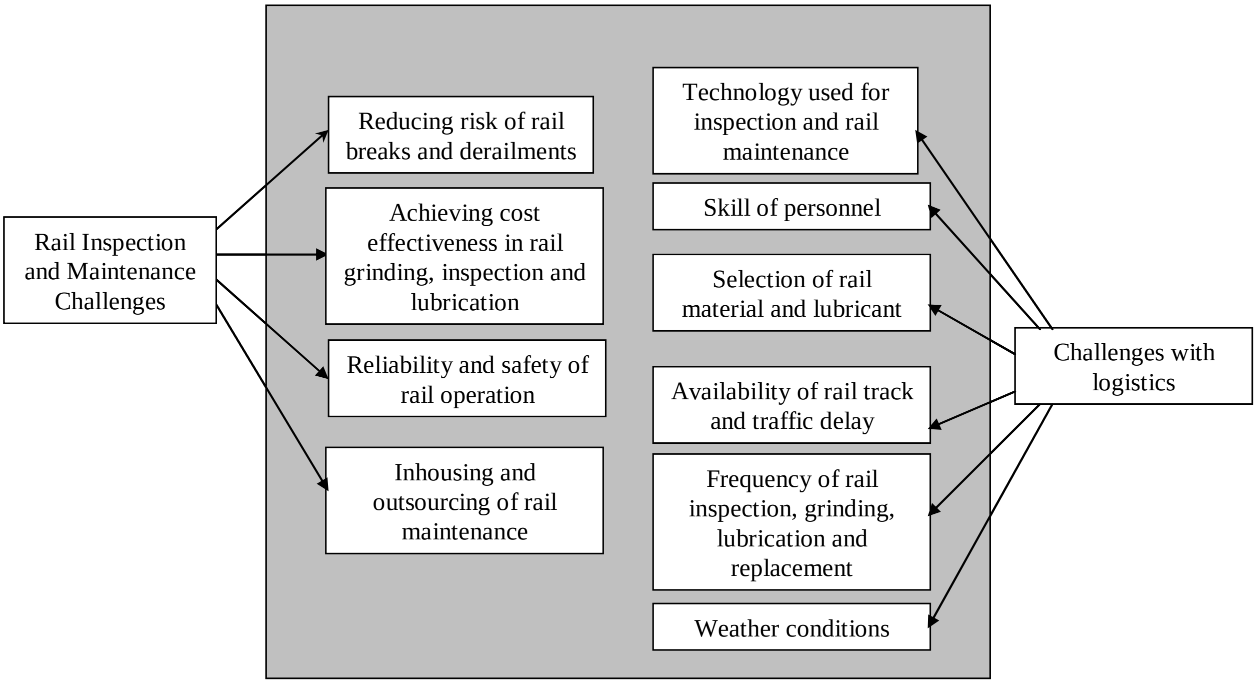

Figure 3. Challenges related to rail maintenance

Logistics is defined as systematic and careful organization of a complicated activity so that it happens in a successful and effective way (Cambridge dictionary, 2006). The equipments and skill required to operate those equipments should be available on time so that systematic inspection and maintenance is carried out effectively. The operating environment has influence on reliability and safety. Selection of material and proper spare part control is also important. Forecasting of required support/spare parts based on technical characteristics helps to avoid unplanned disruptions or stoppages (Ghodrati and Kumar, 2005).

Rail players are looking for cost effective logistics for rail track maintenance to achieve reliable and safe rail operation. The maintenance activities carried out by rail infrastructure owners is known as in-house maintenance. They own maintenance equipments and employ skilled manpower for maintenance activities. But the challenge is how to have the required capacity, efficiency and accuracy of doing all kinds of maintenance activities in a cost effective manner. Outsourcing reduces a lot of expenses and liabilities at the risk of accuracy and response time.

4. CONCLUSION

In this paper the issues and challenges related to logistics of rail maintenance are discussed. The aim is to reduce costs and risks related to rail operation by effective logistics decisions related to rail inspection, grinding, lubrications, rectifications and rail replacements. Some of the challenges in this area include development of cost effective maintenance decisions, reliability and availability of logistics support which include availability of capable equipment, skilled personnel and availability of rail track. The analyses of these decisions need to consider outsourcing of inspection, grinding, lubrication, rectification and rail replacements. Detailed study considering rail and wheel and economic models for logistics decisions is a big challenge now and also for the future. Authors are currently working on these models and the results will be published in the near future.

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