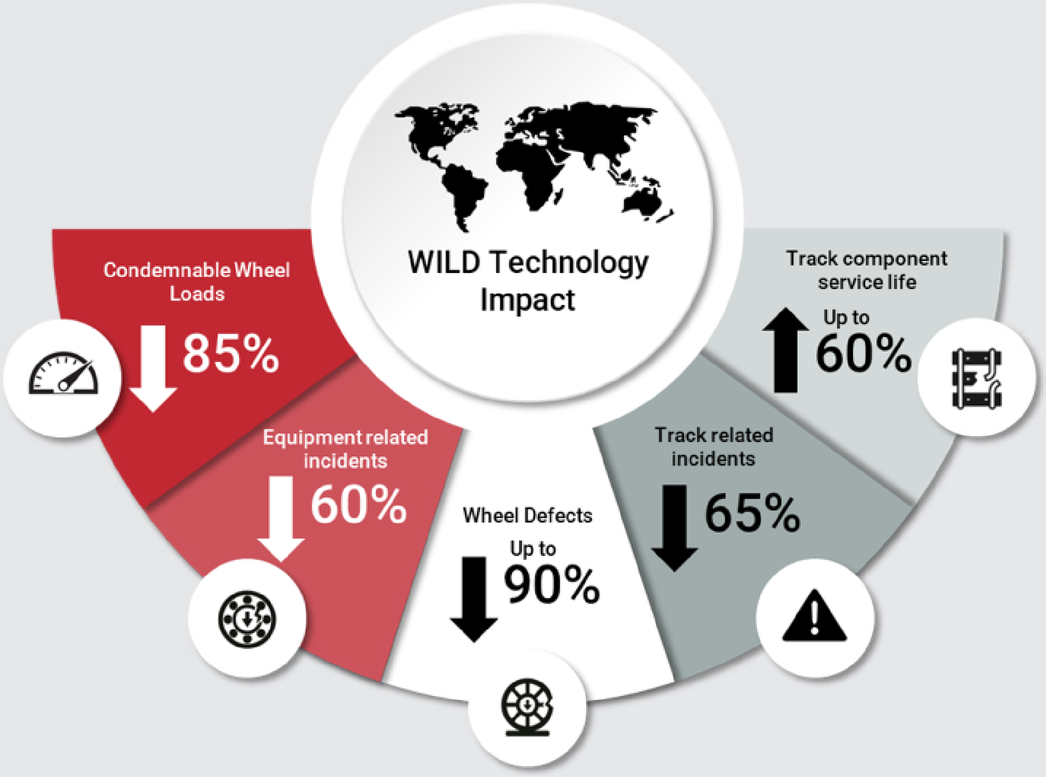
CASE STUDY

TOTALTRACK MONITORING

WILD IV

Qualifying the Benefits of Wheel Impact Load Detection



Forces at the wheel-rail interface are a key consideration for railway networks. For decades, railroads have utilized L.B. Foster's WILD technology to measure forces at the wheel-rail interface.

The WILD IV utilizes an array of strain gauges installed directly on the rail to monitor for high impacts. These high impacts are indicative of hazardous conditions such as wheel defects and improper loading. If left in service, repeated impacts from these conditions can cause damage and premature failure of critical track infrastructure, and in some cases can lead to derailment.

By using impact measurement as a diagnostic tool, users can expect to reduce the number of wheel defects, and costs related to incidents and track maintenance. To understand whether it is cost-effective for an agency to deploy WILD technology (or deploy additional WILD sites along their network), it is necessary to provide an accurate estimate of the expected savings.

Industry research and historical data will be reviewed to show that WILD technology has been used effectively to reduce high impacts, lowering the frequency of costly incidents and extending the service life of track infrastructure.

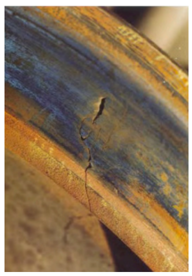
Indentifiable and Preventable Hazardous Conditions Using WILD Technology

By measuring forces at the wheel-rail interface, WILDs can identify defective wheels for targeted removal or maintenance. WILDs may also be equipped with lateral force monitoring which can be used to identify truck performance issues such as wheel climb and hunting.

WHEEL DEFECTS & TRUCK PERFORMANCE

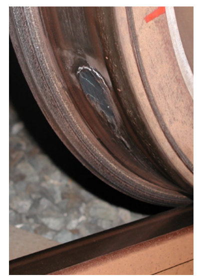
Shelling/Spalling

Rim Fracture

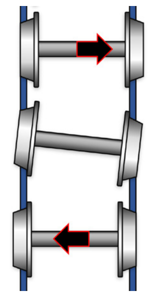


Flange/Tread Wear

Flat Spots



Truck Hunting



Additionally, by analyzing the difference in individual wheel loads many lading issues can be identified:

IMPROPER LOADING

Overload

Imbalance

By identifying and removing wheels generating high impacts, many hazardous conditions related to track equipment and infrastructure damage can be delayed or prevented entirely:

TRACK & EQUIPMENT DAMAGE

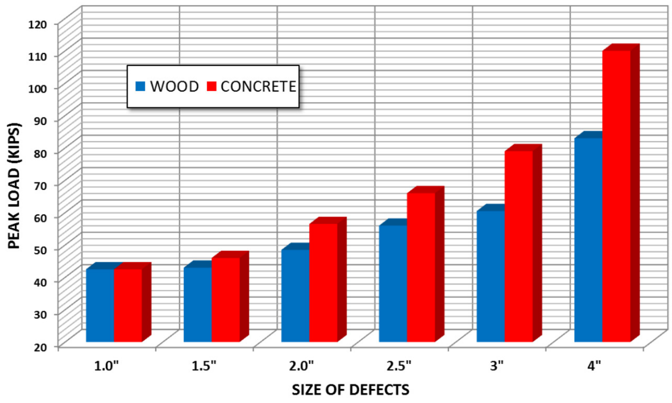
Rail Breaks

Bearing Failure

Tie Failure

High Impacts as an Indicator of Wheel Defects

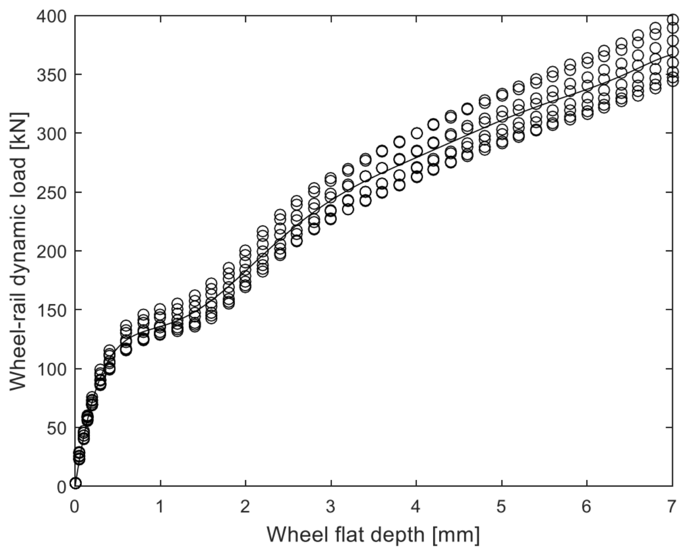
High impacts, or high forces exerted by the wheel onto the rail at the interface, are most often caused by wheel defects. These defects may be produced by material imperfections, acute events such as hard braking or sliding, or by poor rail conditions such as corrugation. Research conducted in India in 2013 and included in a comprehensive report by the FRA in 2019 shows that common wheel defect propagation correlates with increased vertical impacts [1]. By increasing the length of a machined flat, peak load generated by a defective wheel increased from 41 KIPs to as high as 108 KIPs, depending on the support type:



Comparison of impact loads on wood and concrete ties at 40 mph, 100-ton cars, and machined flats [69] (recreated chart).

Data shows that for a given car, the vertical impact from a wheel increases as the size of a wheel defect increases, indicating a relationship between impact magnitude and presence of a wheel defect.

Similar research conducted by Jens Nielsen and published in the International Journal of Rail Transportation identified a similar relationship, showing that as wheel flat depth increased, dynamic wheel load increased by as much as 400 kN (approximately 90,000 lb.) [2].



Nominal Load = The wheel load due to the weight of the vehicle

Peak Load = The maximum load exerted on the rail by the wheel

Dynamic Load = Peak Load - Nominal Load

Research shows that dynamic load increases with the size of wheel flats, also indicating that higher impact magnitudes indicate wheel defects.

High Impacts as an Indicator of Track & Equipment Damage

While high impacts are commonly caused by the presence of wheel defects, they may lead to other hazardous conditions if left in service. Repeated high impacts may lead to failure of vehicle equipment such as wheels and bearings and reduce the service life of track equipment such as rail, ties, switch points, joint bars, and more.

Tie Damage

Preventing damage to concrete ties and extending their lifespan was the original motivation for invention of the WILD. In 1980 AmTrak invested $37 million in concrete ties along its Northeast Corridor (NEC) as part of a massive rehabilitation project. However, as soon as 18 months after installation, many of the ties were exhibiting rail seat cracks which were known to cause premature failure. Subsequent inspections and investigation established that these cracks were being caused by the dynamic wheel/rail loads produced beacuse of wheel-tread irregularities on passenger coaches and freight cars traversing the corridor. To monitor for, and avoid, these high-dynamic forces, the first WILD was developed and installed in 1984.

The results showed that in just a 3-month timespan, the frequency of high impacts decreased by over 60% - but more importantly, none of the cracks already present in the new concrete ties propagated. Based on previous experience, the FRA estimated that removing these high impacts increased the lifespan of the concrete ties from 15-20 years to the intended design life of 50 years [10].

Research today still supports what was discovered over 40 years ago. A report published by RailTec and presented at the 2015 TRB annual meeting demonstrated that wheel loads contributed to multiple concrete tie failure models including rail seat cracks, center negative cracks, rail seat deterioration, and shoulder/fastener wear and fatigue [3]:

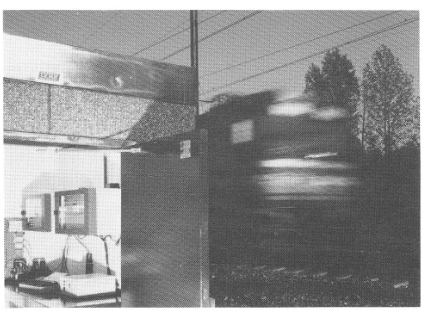


FIGURE 1 WILD installation on Amtrak's Northeast Corridor track near Edgewood, Maryland.

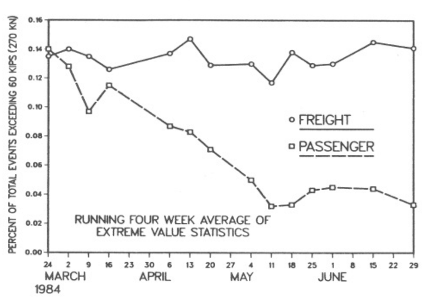


FIGURE 2 Amtrak wheel improvement program results compared with reference weight traffic.

"Wheel impact load detectors (WILD) have been installed worldwide to detect excessive wheel impact loads on tracks, so that defective wheels causing these damaging impact forces can be identified and targeted for removal. The long-term benefits of WILD include not only extended service lives of track components but also reduced energy cost and increased productivity."

Examples of flexural cracks:

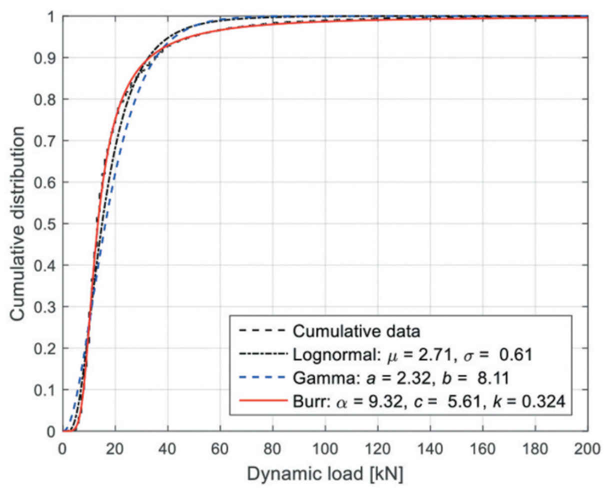
(a) rail seat positive crack.

(b) center negative cracks on concrete ties with abraded bottom.

Rail Damage

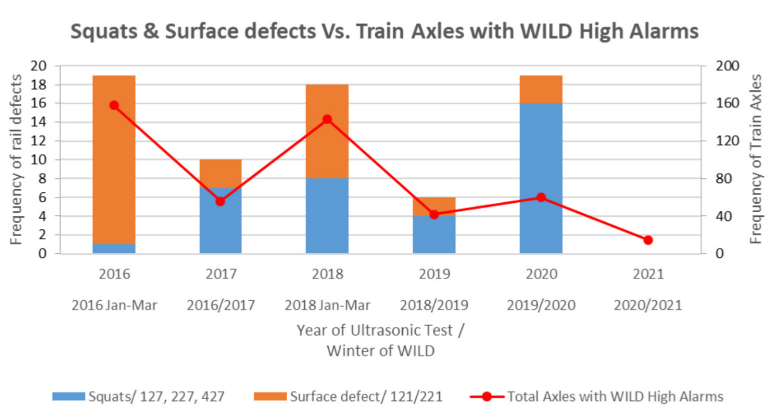
In 2023, the FRA issued a safety advisory encouraging railroads to utilize WILD technology to properly identify and replace high impact railcar wheels, warning that they can cause damage to rails and citing a February 2023 incident that saw 30 coal cars derailed caused by a broken track joint bar [4]. This was the second such safety advisory issued by the FRA, with the first released in 2015. One of the derailed cars was shown to have a measured impact of 130.6 KIPs when it operated over the joint bar that was broken, highlighting the importance of identifying high-impact wheels.

Industry research supports the claim made by the FRA. An investigation conducted by Jens Nielsen and published in 2023 in the Engineering Structures Journal utilized WILD data from the Sunderbyn site in Sweden to create a model that predicted the likelihood of rail breakage due to high vertical loads on a pre-existing rail defect. The model shows that dynamic loads as low as 20 kN (~4,500 lb.) resulted in a nearly 100% probability in defect propagation leading to immediate rail breakage [2]:



Research shows that as dynamic load increases, the probability that a rail defect will immediately fail quickly increases. For certain rail applications, dynamic loads as low as 4,500lb. result in a nearly 100% guarantee in rail failure when a defect is present.

Similarly, a case study conducted at Bodsjon, Sweden aimed to correlate the frequency of rail defect creation with WILD impact alarms. The study also controlled for variables such as vehicle speed, axle weight, ambient temperature, and site traffic. The investigation found that the frequency of rail defects was positively correlated with the number of axles that generated WILD alarms [11].



The case study showed a strong correlation between the number of rail defects present (the bar graph) to the number of WILD alarms (the red line), implying that higher impact magnitudes are causing rail defects to originate or propagate.

Bearing Failure

Bearing failure typically occurs due to failure of the film of oil that provides lubrication. This leads to metal-to-metal contact, excessive friction, and excessive heat. The most common reasons for oil film failure are lack of lubrication and excessive or abnormal loading on the bearing [8].

One of the motivations for the 1999 research conducted by National Rail was an unusually high number of bearing failures, with as many as 1-2 per week in the winter months and an average of 24 annually. Two major root causes for such bearing failures were identified: poor lubrication and excessive wheel loads. To combat the first, a preventive maintenance regime was put into place that involved periodic re-lubrication of bearings. Implementation of WILD technology was selected to address the second, which led to the previously mentioned 90% reduction in serious wheel defects. While the re-lubrication maintenance regime resulted in little improvement in bearing failures, the reduction in wheel defects from WILD technology resulted in an approximately 85% reduction, decreasing bearing failures from 24 annually to just three in 8 months. Of the three that occurred in the 8-month timeframe, all three were detected by their WILD.

Additionally, National Rail found that the WILD provided a more reliable method of identifying defective wheels and bearings than aural or visual inspection, evidence by derailments attributed to wheels that had recently been inspected.

"Where the defect data and inspection do not agree, the growing trend... is for WILD to override the inspection results. This is due to the repeatability of the data from one pass to the next plus the fact that trains that produce alarms have been inspected and confirmed as OK only to derail soon afterward. This strongly supports the system's ability to detect defects that cannot be detected by visual inspection methods."

An inspection report from National Rail in February, 1999, is summarized as follows:

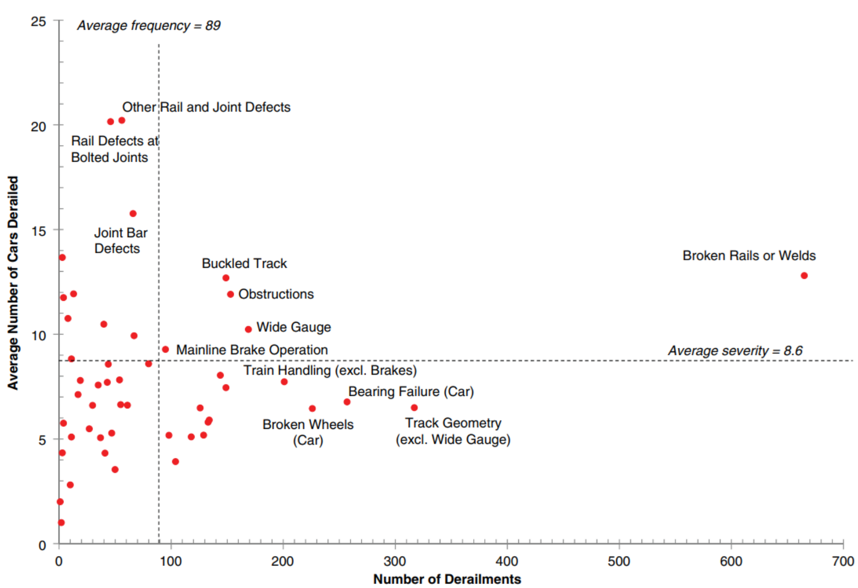
1. 36 wheelsets inspected, increased from 4 inspected in January due to reviewing inspection standards as a result of characteristics displayed (via WILD) by wheelset/hot-box failures at Tottenham and Port Augusta in early January (1999).
2. 15 (or 42%) of wheelsets inspected were replaced. Of these, 12 were 18R bearings, 2 were 50t bearings, and 1 was a 70t bearing.
3. Most, if not all, were not picked up during train examination.
4. Most were changed out in accordance with NR standards.
5. All displayed similar impact characteristics.

Leading Causes of Derailment

The primary objective of WILD technology is to reduce the likelihood of derailment and incidents. As such, it is important to know how much the hazardous conditions identified by WILDs contribute to derailments, and how effectively they can be mitigated or prevented. A comprehensive report published by RailTec in 2010 reviewed the root cause of derailments from the prior decade and found that track equipment damage and wheel defects are some of the leading causes of derailment. In fact, hazardous conditions that can be identified and prevented by WILDs account for approximately 40% of all derailments [5]:

Cause Group	Description	Number of Derailments	Percentage of Derailments	Cars Derailed
08T	Broken Rails or Welds	665	15.3%	8,512
10E	Bearing Failure	257	5.9%	1,739
12E	Broken Wheels (Car)	226	5.2%	1,457
11E	Other axle or Journal Defects	144	3.3%	1,157
03M	Lading Problems	134	3.1%	791
13E	Other Wheel Defects (Car)	129	3.0%	668
07T	Joint Bar Defects	66	1.5%	1,040
15E	Loco Trucks, Bearings, Wheels	50	1.1%	177
20E	Track-Train Interaction (Hunting)	40	0.9%	419

Additionally, certain preventable hazardous conditions such as rail breaks and bearing failures tend to lend to more severe derailments (as measured by the average number of cars derailed) [5]:



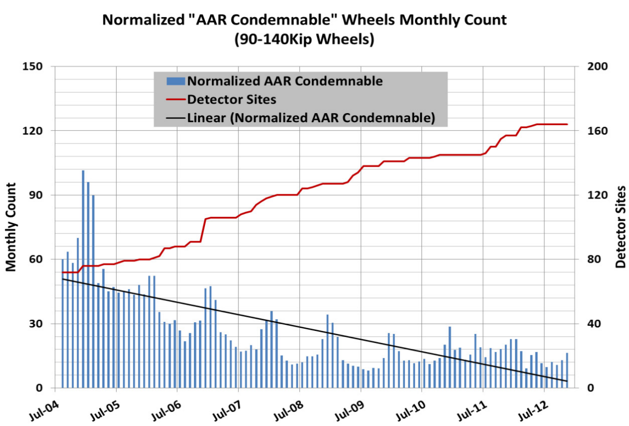
Frequency and severity graph of Class I main-line freight train derailments, 2001-2010.

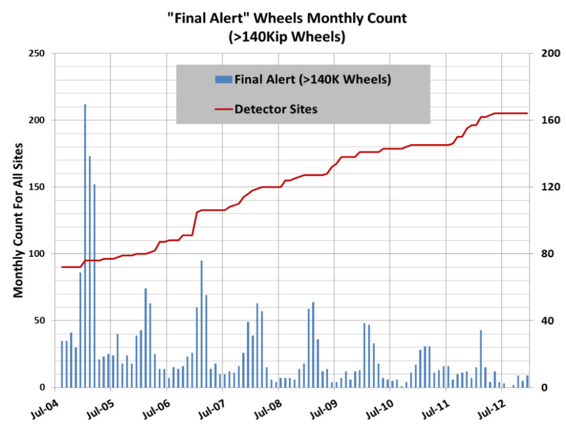
Reduction of High Impacts from WILD Technology

It has been established that the presence of high impacts is a strong indicator of wheel defects which not only contribute directly to derailments but also can damage track infrastructure and equipment. Track & equipment damage adds additional risk of derailment and a large cost to the industry to maintain and replace such infrastructure. It is then critical to determine how effective WILD technology is at detecting and reducing the presence of high impacts on rail networks.

WILDs saw widespread adoption in the early to mid 2000's, and as such this time provides a basis for comparison to determine the effectiveness of the technology. Also starting in July 2004 wayside detector data began to be collected and stored through InteRRIS under the AAR's Advanced Technology Safety Initiative (ATSI). This data can be used to track the reduction in high impacts during the 2000's.

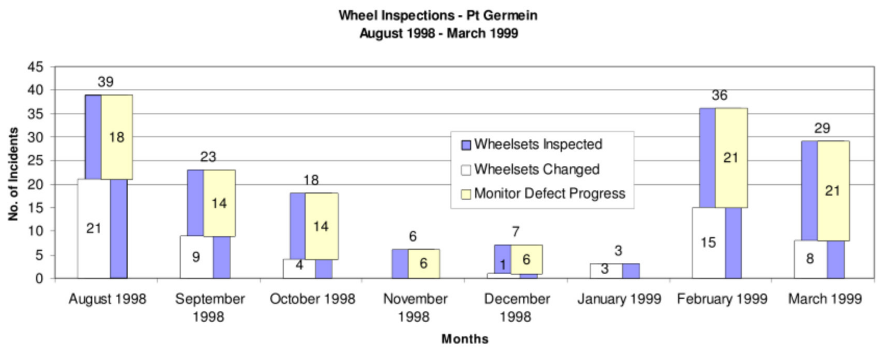
According to a report published by the FRA in 2022, between 2004 and 2012 the number of WILD detectors in the industry increased from 54 to 163. In that same span of time, the number of condemnable wheels (vertical impact between 90 and 140 KIPs) decreased by as much as 85%, and the number of 'final alert' wheels (vertical impact >140 KIPs) decreased by as much as 95% [6]:





"These figures also show a dramatic impact of WILD installations on the number of wheels that produce truck damaging vertical loads. Whereas, for the queried car population, there were over 250 wheel counts at "Final Alert"--highest in winter months--level per month in 2004 with half the number of detectors in the network, that count has dwindled to only 5-6 per month in 2012."

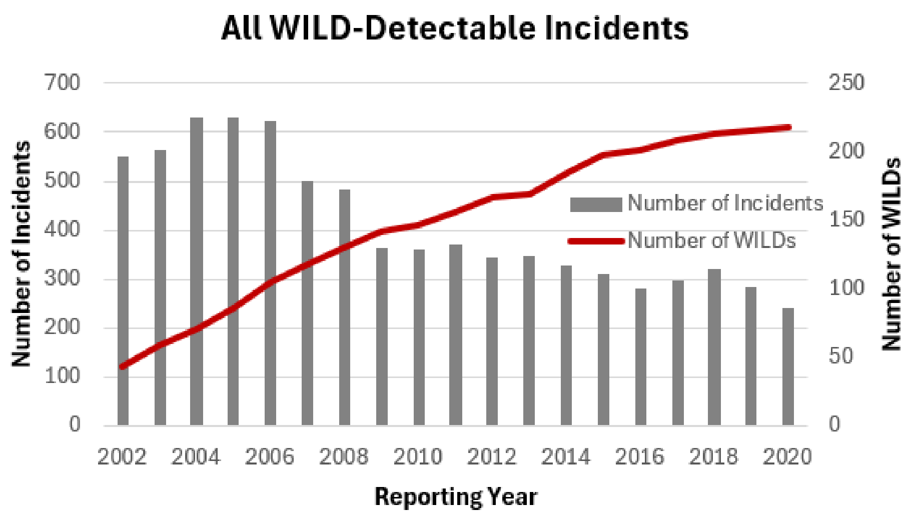
Additionally, the 1999 National Rail (NR) report found that installation of a single WILD detector resulted in a real reduction in serious wheel defects of 90% over 6 months [7]:



Incident Reduction & Prevention

While reducing the presence of wheel defects and high impacts on rail networks has its own merits related to operational efficiency and maintenance costs, the primary motivation for most railroads is to reduce the likelihood of derailments and other incidents. Like the comparison made to determine the effectiveness of WILD technology at reducing high impacts, incident data from the 2000's and onward can be investigated to characterize its effectiveness at preventing or reducing the likelihood of derailment.

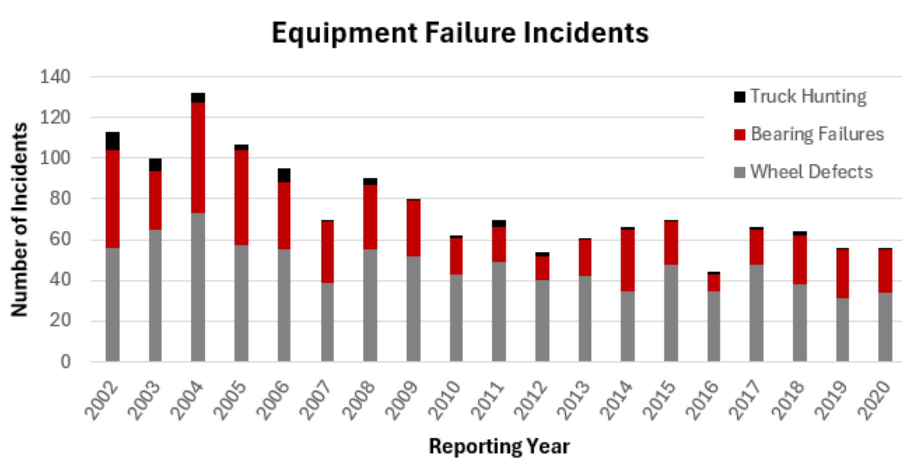
Incident data published by the FRA's Office of Safety Analysis shows that from 2002 to 2020, a timespan in which the number of WILD detectors increased from less than 50 to more than 220, the frequency of WILD-detectable incidents decreased by over 50%, from as many as 631 per year in the mid 2000's to less than 250 in 2020.



Equipment Failure Incident Reduction

WILD-detectable equipment failure incidents include wheel defects, bearings failures, and truck hunting. Accidents with the following cause codes were tracked from 2002 through 2020:

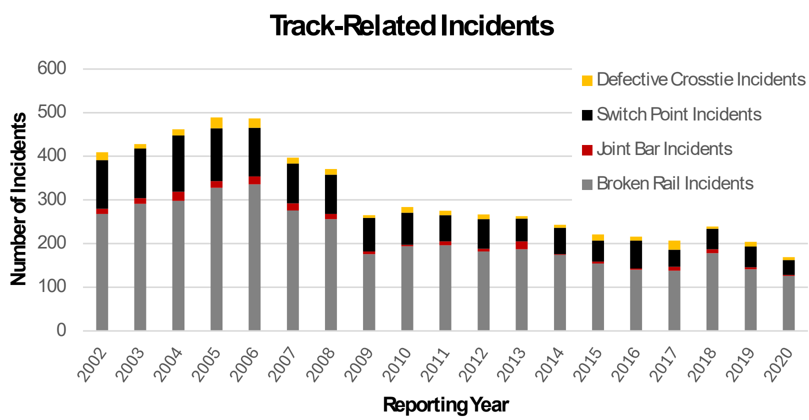
- E61 (Broken Rim)
- E67 (Flange Build Up)
- E64 (Worn Flange)
- E69 (Other Wheel Defects)
- E68 (Loose Wheel)
- E60 (Broken Flange)
- E65 (Worn Tread)
- E66 (Flat Spot)
- E53 (Journal Bearing Overheat)
- E42 (Broken Side Bearing)
- E59 (Other Bearing Defects)
- E4T (Truck Hunting)



Track-Related Incident Reduction

WILD-detectable track-related incidents include broken rails, joint bars, crossties, and switch points. Accidents with the following cause codes were tracked from 2002 through 2020:

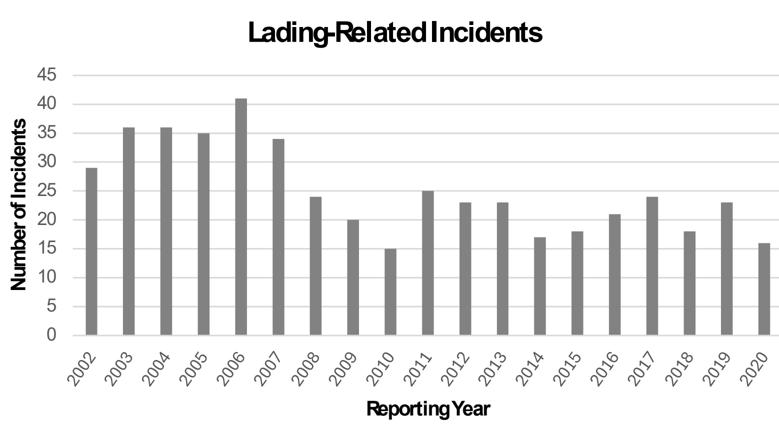
- T201 (Broken Rail, Bolt Hole Crack)
- T202 (Broken Rail Base)
- T203 (Broken Rail, Plant Weld)
- T204 (Broken Rail, Field Weld)
- T205 (Defective or Missing Crossties)
- T207 (Broken Rail, Detail Fracture/ Shelling/Head Check)
- T210 (Broken Rail, Head and Web Separation, Outside)
- T211 (Broken Rail, Head and Web Separation, Inside)
- T212 (Broken Rail, Horizontal Split Head)
- T213 (Joint Bar Compromised)
- T214 (Joint Bar Broken, Insulated)
- T215 (Joint Bar Broken, Non-insulated)
- T216 (Broken Joint Bar Bolts)
- T219 (Rail Defects w/ Joint Bar Repair)
- T220 (Broken Rail, Transverse/Compound Fissure)
- T221 (Broken Rail, Vertical Split Head)
- T222 (Worn Rail)
- T229 (Other Rail & Joint Bar Defects)
- T311 (Switch Damaged)
- T314 (Switch Point Worn or Broken)



Lading-Related Incident Reduction

WILD-detectable lading related incidents include improperly loaded cars, overloaded cars, and load shifts. Accidents with the following cause codes were tracked from 2002 through 2020:

- M201 (ILoad Shifted)
- M204 (Improperly Loaded Car)
- M203 (Overladed Car)
- M207 (Overloaded Container)
- M208 (Improperly Loaded Container)

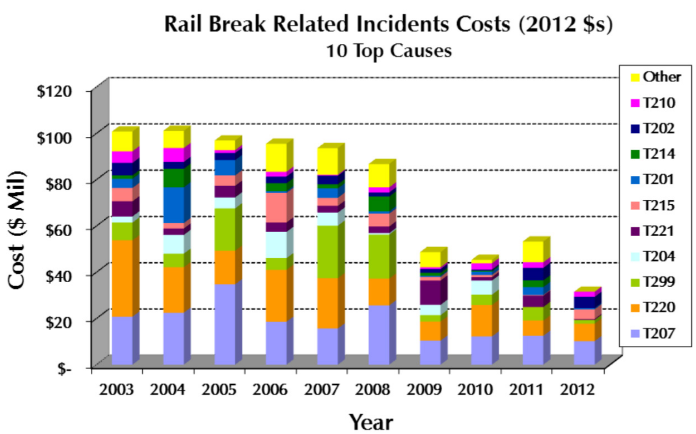


Conclusions

Industry research and historical data supports the claim that high impacts play a significant role in many common rail incidents. Data also shows that these high impacts are commonly caused by wheel defects, and through identification and targeted removal of these wheels, the rail industry has seen drastic reductions in incidents related to track and equipment damage.

Furthermore, several organizations and researchers attribute WILD technology with widespread improvements in network operations, productivity, and reliability, citing its ability to identify hazardous conditions that are often missed by visual and aural inspections.

Through effective deployment of this technology, the rail industry has reduced spends related to track and equipment maintenance exceeding $100 Million annually, not accounting for indirect savings through increased operating and labor efficiency.



A summary of industry spend for rail breaks through the 2000's shows a real annual savings of nearly $70M 2012 USD (~$100M 2025 USD) through reduction of a single hazardous condition detectable and preventable using WILD technology.

Based on the average cost of a derailment (approximately $432,000 2025 USD), reducing their frequency has also resulted in direct industry savings of $33-40 Million annually. Derailment prevention also improves network safety, aligns with corporate strategies, and improves public relations for railroads.

The WILD remains a critical safety solution for any rail agency, offering significant savings by preventing hazardous conditions, enhancing safety, improving efficiency, and protecting track infrastructure.

References

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