

# Overview of issues and research related to special trackwork for shared high-speed-rail passenger and heavy-axle-load freight operations

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## Abstract

Special trackwork, including turnouts and crossing diamonds and their components, plays a vital role in railway infrastructure by providing route flexibility to trains as they travel across a network. As the interest in shared rail corridors involving heavy-axle-load freight traffic and high-speed-rail passenger traffic grows, special trackwork represents a significant challenge due to diverging loading characteristics and design priorities. This paper presents an overview of the issues related with special trackwork for shared rail corridors, as well as an in-depth analysis of the relevant research to date. The relevance of different shared operation types and research needs are also presented. This study can be used to assist in the planning of new passenger services on freight rail lines, or vice versa, in the USA, and may also be relevant to shared rail corridor development in other countries.

## Keywords

Special trackwork, turnouts, crossing diamonds, shared corridor, high-speed rail

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## Introduction

The nature of the structure of railroad tracks creates a unique challenge at the point where two tracks intersect. Special trackwork, such as turnouts and crossing diamonds and their constituent components, plays a vital role in railway infrastructure by providing route flexibility to trains as they travel across a network. Discontinuities in wheel/rail contact at the running surface and increased stiffness levels of special trackwork result in high impact loads and dynamic interactions between rail wheels and the specialty components that constitute turnouts and crossing diamonds.<sup>1</sup> Discontinuities in the track are critical because they alter the vertical and lateral stiffness levels of the track and affect the speed of the vehicle.<sup>2</sup> As a result of these interactions, a significant amount of damage to the track ensues in the form of plastic deformation, component wear and rolling contact fatigue.<sup>1</sup> Although special trackwork typically constitutes only a small portion of route miles on a railway network, problems with turnout and crossing components represent a relatively large percentage of maintenance costs, train delays and track-related incidents.<sup>3,4</sup>

The US Department of Transportation is supporting development of substantially expanded and improved passenger rail service on a number of intercity corridors across the USA.<sup>5</sup> These corridor development projects range from incremental improvement of existing tracks to construction of new, dedicated high-speed rail (HSR) lines. Many existing lines already support freight and passenger rail services, necessitating shared operations. As the interest in shared corridors with shared track grows, special trackwork represents a significant challenge due to diverging loading characteristics and design priorities of heavy axle load (HAL) freight traffic and HSR passenger traffic.<sup>6</sup>

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### *Divergent design considerations for HSR and HAL*

Special trackwork design in North America has progressed mainly with a focus on increased axle loads and as a result operating speeds have not seen similar increases. Consequently, track component designs have become stronger, albeit larger, yet the actual geometry of turnouts and other track components has not significantly altered.<sup>7</sup> Thus, there exists the challenge to the North American railway infrastructure of accommodating proposed higher-speed passenger services, which requires a higher standard for track quality, onto existing track typically experiencing HAL freight operations. In order to meet the track design conditions required for the growth of HSR in North America, the design of the turnout must be reanalyzed. Many other countries, specifically those in Europe and Asia, can provide valuable insights into track design for high-speed operation.<sup>8–10</sup> However, there is still much to be learned about operating on shared track, as the combination of North American freight axle loads and more robust passenger car designs than those generally seen globally on existing high-speed lines exacerbates this challenge.<sup>7</sup>

Both HAL and HSR types of traffic require special trackwork components that minimize impact loads.<sup>11</sup> However, notable differences between HAL and HSR in terms of design requirements and loading conditions have created a variety of challenges related to special trackwork. The primary difference is the priority given to considerations for passenger comfort and diverging speed. HSR lines require that turnouts and crossings minimize or eliminate the need to slow the train while maintaining passenger safety and comfort.<sup>11</sup> Increases in diverging speed and rider comfort can be achieved through optimal turnout geometries and the use of movable point frogs.<sup>11</sup> Another alternative is to orient turnouts such that the direction of high-speed traffic corresponds with the straight movement through the turnout. On the other hand, special trackwork on HAL freight lines is designed to withstand the high tonnage on a specific route while minimizing maintenance.<sup>11</sup> Since the diverging speed is typically less important on HAL lines, the goal of innovative frog designs for HAL is to eliminate the gap in the running rails on the mainline. This may be achieved through flange bearing frogs or spring frogs.

In addition to design considerations, HSR and HAL operations impose different loading conditions on special trackwork. Impact loads vary significantly with train speed, and are the primary cause of track degradation.<sup>12</sup> Both HAL and HSR traffic impose impact loads due to irregularities in the track and in the wheels, but the combination of axle load and train speed makes the differences in load magnitude and track damage extremely complex. By definition, the loads from HAL freight trains are higher in magnitude and longer in duration than loads from HSR

trains. When irregularities incite dynamic interaction between rails and HAL wheels, a dynamic amplification of the load magnitude can occur at higher frequencies. HSR loads have a lower magnitude, but the faster speeds result in a greater amplification of the forces. For example, one study has shown that the wheel/rail contact force in a turnout is approximately 100% greater than the static load for trains traveling at 70 km/h and 200% greater at 150 km/h.<sup>13</sup>

In order for incremental upgrades to result in a successful HSR system, special trackwork must meet the design requirements necessary to run passenger trains at high speeds while withstanding heavy impact loads from HAL freight cars. This paper presents an overview of the issues related with special trackwork for shared corridors, as well as an in-depth analysis of the relevant research to date. In the following section, a review of studies related to flange bearing technology, turnout geometry, other innovative component designs, and field instrumentation and modeling is presented. In the discussion section, the relevance of different shared operation types and research needs are addressed.

## **Review of previous related research**

### *Flange bearing technology*

Railroad crossing diamonds require improvement as the demands on the track become more significant due to increasing axle loads and faster train speeds. The traditional approach to the design of crossing diamonds is to create small gaps in the intersecting rails to allow a train to pass through another track without having to separate the grade of the two lines. High impact loads from railcar wheels are often imparted on the edges of the frog where these gaps occur, which greatly increase wear and reduce the life cycle of these components. Not only do these high impact forces cause damage to the rail, but the supporting earthwork below a crossing diamond is also negatively affected. In an attempt to mitigate these impacts under increasing axle loads, and increase the life cycle of crossing diamond components, Class I railroads have been investigating the use of flange bearing technologies.<sup>14</sup> With flange bearing technology, the gap in the running surface of the rail is eliminated because the flange of a wheel is used to support the railcar as it is essentially lifted over the intersecting track.

One type of flange bearing technology is a full flange bearing frog (FBF) diamond as shown in Figure 1. In this type, wheels on trains traveling on both tracks at a crossing are ramped up and supported by the flanges so that intersection occurs at the same level surface for both routes.<sup>14</sup> The elimination of flangeway gaps for both routes mitigates the issue of high impact forces on the components of the crossing diamond. The Federal Railroad



**Figure 1.** Example of a FBF diamond. Reproduced with permission from the American Railway Engineering and Maintenance-of-way Association.



**Figure 2.** Example of an OWLS partial flange bearing line. Reproduced with permission from the American Railway Engineering and Maintenance-of-way Association.

Administration (FRA), however, does have a regulation governing flangeway depth of railroad track components, necessitating the request for a special waiver to make use of this technology. A field installation of a FBF diamond was performed at Shelby, Ohio by CSX in 2006. Within the first 22 months of service, practically no maintenance related to this diamond was required despite it having supported approximately 60 MGT per year since its installation.<sup>14</sup> Although the speed on both routes had to be reduced to 40 miles/h, an advantage of this technology is that the relative speed of each route can be the same. Further evaluation on the potential longer life cycle of this crossing is still being performed. This type of diamond may be beneficial at a crossing where the freight and passenger traffic volumes on each line are similar. Because of the lower speeds required on FBF diamonds, this technology would not be ideal where higher-speed operation is desired. Further research may lead to increased speed operation through geometric and material improvements.

Another popular type of flange bearing technology is the one-way low speed (OWLS) partial flange bearing crossing diamond (Figure 2). This technology was developed in response to the requirement to obtain a waiver of the FRA Track Safety Standards in order to make use of FBF diamond crossings. In this application, the rail on a line with a large volume of traffic can be left continuous, while the intersecting line with less traffic becomes flange bearing as it crosses over the mainline. The geometry of an OWLS diamond still requires a gap on the flange bearing track to go over the continuous rail. The lower frequency of impact loadings on this track results in less damage to the frog. An example of where this type of crossing could benefit operations and maintenance would be a low-used branch line intersecting a busy, high-density mainline. It should be noted that research into flange bearing technology has shown that it does not have a negative effect on freight car or locomotive wheels.<sup>14</sup> This type of diamond would be ideal in a shared

corridor where there is predominance in traffic volume on a given line over an intersecting line that is operated at lower speeds. The low-used line would be flange bearing through the diamond, allowing the other to be continuous, benefiting by unrestricted speeds and providing a smooth running surface for passenger comfort.

Flange bearing technology has also been adapted for turnouts, through the use of a partial flange bearing turnout frog. In this application the rail of a mainline route can again remain continuous, since the low-used diverging track is used to lift the train wheels over the mainline rail, and is lowered down to continue on the diverging route.<sup>15</sup> This type of turnout is said to be more effective than a commonly used spring frog because there is no need for moving parts and the additional inspection and lubrication necessary for that type of trackwork.<sup>14</sup> Because the point of a frog is generally an area experiencing high impact loads in more typical designs, elimination of this area can increase the life cycle of the expensive track component.

A test installation on the Facility for Accelerated Service Testing (FAST) at the Transportation Technology Center included two different prototypes of partial flange bearing turnout frogs. One of these is called the lift frog, and is similar to turnouts that the railroad companies are currently purchasing. The lift frog is unique because of an increased ramp length in the frog, and the presence of a parallel ramp on the guardrail side of the turnout opposite the frog.<sup>15,16</sup> At FAST, this frog was installed on a turnout on the high tonnage loop, which experiences 39-ton axle loads operating at 40 miles/h. When comparing the results of vertical wheel forces for the lift frog with those for a rail bound manganese (RBM) frog installed at this location, the vertical wheel forces experienced by the frog from the mainline traffic were seen to be significantly reduced.

A diverging move made over this turnout is limited to 10 miles/h for freight and 15 miles/h for passenger

trains. However, it is generally the higher operating speeds that produce increased dynamic impact loads, and so a reduction of the force from the faster, main-line traffic results in a very positive result. The benefit of reduced forces at this speed is that a longer service life for the lift frog is expected as compared with the more commonly used RBM frog. In a potential shared track operation, partial flange bearing turnout frogs such as the lift frog could be used where a track diverges into respective freight and passenger routes. It should be noted that in a shared track scenario the ramps in partial flange bearing turnout frogs must be designed to accommodate a greater variety of wheel flanges. Different types of freight and passenger rolling stock have wheel profiles optimized for their given performance requirements. Subsequently, special trackwork on shared corridors must be designed so that both types of wheel profiles can navigate the gaps in the frog.

### Turnout geometry

Another aspect of the challenge of operating high-speed passenger trains on existing freight lines is the geometry of the turnouts. The primary influence on selection of turnout frog angle, which governs the rate at which two tracks diverge, is the desired operating speed through the turnout. Conversely, existing turnouts restrict increases in the speed of train operation through certain sections of track. Turnouts designed for high-speed operation are generally longer in length in order to reduce lateral accelerations and provide a more gradual change of direction. Too rapid a change in lateral acceleration can cause a phenomenon known as entry “jerk,” which causes passenger discomfort.<sup>7</sup> Passenger comfort is a critical factor that has resulted in the requirement to rigidly adhere to high maintenance standards for HSR. Consideration should be taken to ensure that new turnout designs for existing track meet the dynamic responses necessary to safely increase speeds.<sup>7</sup>

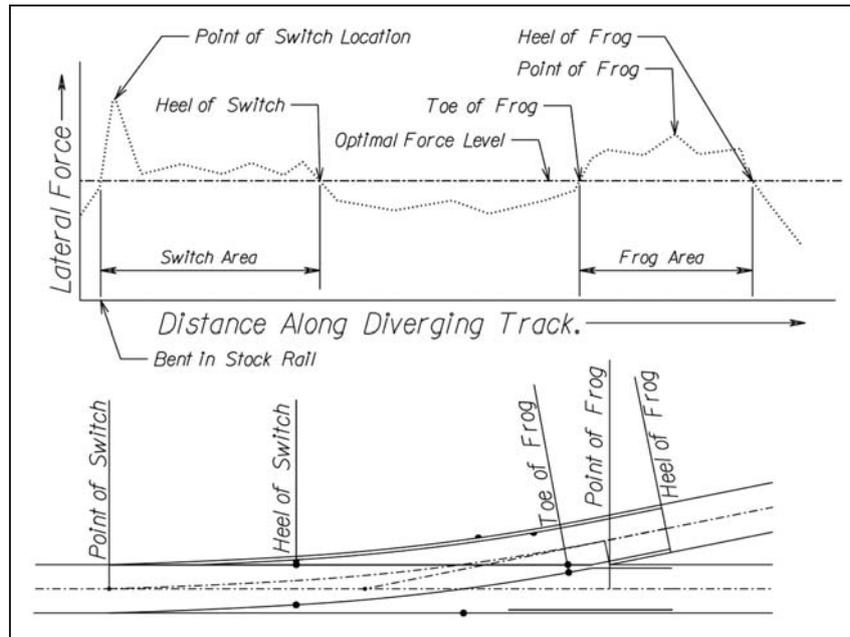
Research is being performed on increasing the operating speed of trains through the diverging route of a turnout while maintaining the same turnout footprint, that is, without changing the basic track infrastructure layout.<sup>17</sup> The goal of the research is to maintain the same locations of the point of switch (PS) and point of frog (PF), and keep the frog angle as a fixed parameter. Any redesign of the turnout would focus on the area between the PS and PF. The issue is that a train diverging through a turnout causes high lateral forces as a result of centripetal action on the car body, and these forces vary with the geometry of a given turnout. The forces imparted on turnout components are often greater than their designed strength values. To mitigate this, changes in the turnout design should be made to ensure that the forces remain within the tolerable region.<sup>17</sup> Figure 3 illustrates various components of a turnout

where lateral forces can exceed this optimum force level, and thus should be targets for analysis and potential redesign. The ultimate goals of increasing diverging speed through a turnout within the same footprint with reduced lateral forces and accelerations are to improve ride quality and decrease component wear. Higher diverging speeds can also increase the capacity of a railroad system.<sup>17</sup>

It is likely that upgrading a single turnout will have no major effect on increasing the capacity of a line. Rather, a greater amount of improvement can be achieved by performing low-cost modifications to several turnouts over a given section of rail line, which would increase the average speed of the trains over that section.<sup>17</sup> Increasing the average train speed in a shared corridor can mean more operating revenue for freight companies, and shorter travel times for passenger trains. Prasad<sup>17</sup> proposed the approach of identifying the components and locations in a standard turnout that cause speed restrictions: the toe of the switch which causes both a kink in the alignment and a change in curvature; the heel of the switch which causes a change in curvature, the toe and heel of the frog which both cause a change in curvature; the gap at the “V” of the crossing where high vertical impacts can occur, and the lack of cant/superelevation in the lead curve on which high lateral forces act.

Several constraints exist on the geometry of a turnout that can be optimized to create the desired results. These constraints are the lead distance between the PS and PF, the interlocking footprint of the turnout, the frog angle, and the location of the PS and PF.<sup>17</sup> The reasons these constraints are considered is that they can be used to avoid an extreme case of turnout rehabilitation, and that changing any of these geometric values will induce the high cost of changing basic track infrastructure. The aims of modifying existing turnouts for higher diverging speeds include higher line capacity, better ride quality and comfort, reduced lateral wheel forces and acceleration, predicted rail wear rates, longer service life, and minimum life cycle cost with less interruption of traffic for repair or reconditioning of turnout.<sup>17</sup>

Research on optimizing turnout design was furthered through field testing performed by VAE Aketiengesellschaft on the response of a standard AREMA no. 20 turnout, and an optimized no. 20 turnout to the wheel/rail forces from the leading axle of a train. The optimized turnout comprised of back-to-back spirals with larger radii entering and leaving the turnout, and a smaller radius in the body of the turnout. Use of a larger radius for switch entry for the diverging rail through means of a spiral allows a smaller entry angle of a turnout, which lowers lateral forces and acceleration, and allows a higher diverging speed.<sup>3,7</sup> The result of this optimized design was that while maintaining the same lead length and turnout angle as the standard no. 20 turnout, the optimized turnout saw lateral forces



**Figure 3.** Concept of optimum lateral force in a turnout design.

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reduced by approximately 40%.<sup>17</sup> Operating speeds for this test were 40 miles/h which is more representative of freight train operation. Figure 4 shows results from a test of lateral forces produced by a 110-ton coal hopper car traveling at 40 miles/h through three different turnout types.<sup>3</sup> One of the tested turnouts consisted of larger entry and exit radii, meaning it had been created with spiral transitions into and out of the turnout. From these results it can be seen that this design for the geometry of a turnout can significantly reduce lateral loads from freight train operations.

A similar test was conducted by Butzbacher Weichenbau GmbH in order to compare wheel/rail forces from the leading axle in two high-speed turnouts: one with kinematic gauge optimization (KGO) and one without. KGO is an innovative turnout design where the track gauge is widened at the switch entry area, reducing lateral impact loads.<sup>7</sup> It does so by causing the wheels to ride outwards on the taper of the tread, thus steering a train car away from a closed switch point.<sup>7</sup> This also allows for the switch rail to be thickened, reducing wear on this component and increasing its life cycle.<sup>18</sup> This gauge-widening concept is demonstrated in Figure 5. Immediately behind the wheels, an exaggeration of the widened gauge is depicted. It can be seen that the lines of contact between the rail and the wheel tapers have been moved outward relative to the track centerline. This can be compared with the case where this contact would occur under a normal design where the gauge remains constant through the turnout.

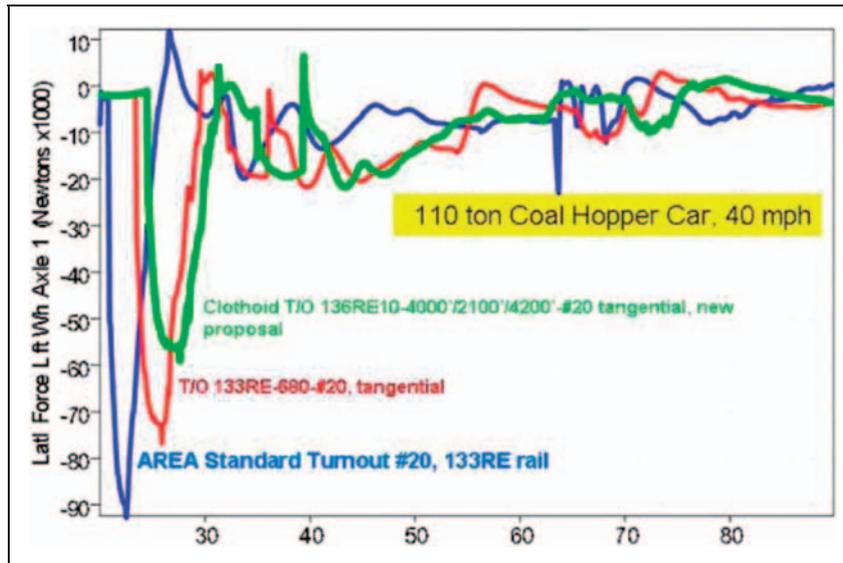
Operating speeds for this test were 190 miles/h for the mainline and 140 miles/h for the diverging route,

thus this test allowed the effects of changing internal turnout geometry for high-speed operation to be comprehended. The results from this study also showed a 40% decrease in maximum forces for the turnout with KGO, which increases the life of the turnout components.<sup>17</sup>

Several design proposals for turnouts have been identified in order to increase the diverging speed within the same interlocking footprint of existing turnouts.<sup>7,17</sup> The first is to reduce the angle for switch entry, thereby reducing the angle of attack and lateral forces and minimizing the “jerk” forces that cause passenger discomfort, which can be done through use of curved switches. Designing turnouts with transition curves in components such as the switch rail, lead rail, closure rails, or at points between the PS and PF can mitigate unbalanced forces on the wheelset of a passing train. Making use of KGO technology and creating back-to-back spirals within an optimized turnout design can reduce wheel/ flange contact on the gauge side which in turn can minimize wear on the switch components. Use of clips and special clamps on the gauge side of the running rail or guard rail can allow for more simplified removal of these components when worn significantly, decreasing track maintenance time. There is also potential for improved design of rolling stock suspension systems to better absorb lateral forces, allowing for greater diverging speeds and increasing passenger comfort.

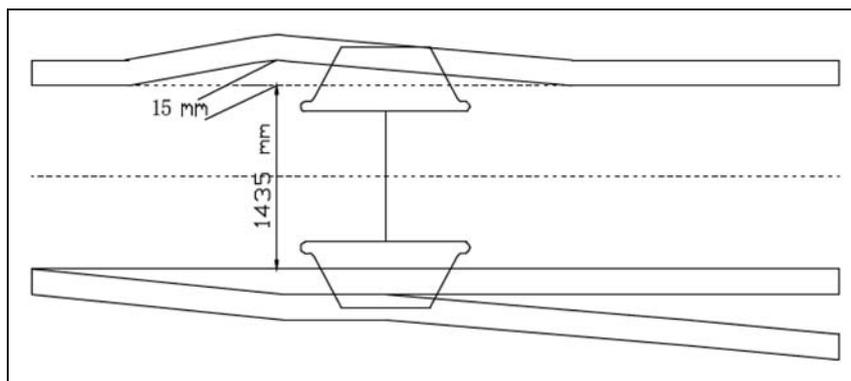
### *Other innovative component designs*

Another important aspect of special trackwork is the design of the supporting cross ties. For the purposes of heavy freight loads and high-speed operation,



**Figure 4.** Comparison of switch geometries.

Reproduced with permission from Sage Publications (Ossberger and Bishop, 2010).



**Figure 5.** Gauge-widening switch structure.

Reproduced with permission from the American Society of Civil Engineers.

concrete cross ties are considered to be the most effective material choice. Often specially produced long cross ties are used in the transition area of a turnout before the two diverging tracks become far enough apart that separate series of cross ties can be used. Concrete cross ties have been produced that are 25 ft or greater in length; however, it can prove difficult to transport and install them.<sup>7</sup> A solution to this is the use of long tie connections that can connect two typical cross ties. An advantage of using this type of connection between two smaller cross ties is that it minimizes adjacent track fouling created by the large machinery necessary to install very long cross ties.<sup>7</sup>

A design factor in many turnouts is the presence of a switch machine to align the points for movement of rail traffic on the desired route. For smaller-sized turnouts, a single switch machine is often adequate to provide the power needed to move the switch

points. With the implementation of the larger turnouts necessary for high-speed operation, more power is needed to move the longer rail components. To provide a smoother ride for passengers and for safety reasons, it is necessary that the whole point is moved uniformly.<sup>7</sup> Currently, more support locations along the moving point are necessary to successfully “throw” the switch in some larger turnouts.

High-speed turnouts not only require an adequate number of these supporting locations for proper alignment, but in some cases multiple switch machines are necessary to provide adequate power to do so. For example, for a no. 45 high-speed turnout, six switch machines are currently necessary to move the switch point, and three more are required if the turnout contains a moveable point frog.<sup>7</sup> As a solution to this problem, a type of turnout where multiple slave drive units are connected by hydraulic lines to a primary active unit has been successfully used in Europe.

This design allows the forces necessary to move the switch point to be applied simultaneously.<sup>7</sup> This type of turnout can make for smoother and safer high-speed operation of the turnout.

### *Field instrumentation and modeling*

Several research projects have been conducted with the objective of understanding the dynamic interactions of special trackwork through field measurements and finite element modeling. Kassa and Nielson<sup>1</sup> instrumented wheelsets to measure vertical and lateral contact forces on the wheels on a test train as it traversed a standard UIC60-760-1:15 turnout. The field data was used to validate two models that predicted the vertical and lateral forces with “acceptable” agreement.<sup>1</sup> The influence of train speed, train orientation (facing or trailing move) and train route (main or diverging route) was analyzed with data from the field and the results of the model. The train route had the most significant impact on the maximum vertical and lateral contact forces, with the highest forces occurring when a train made a facing move on the diverging route. Contact forces increased with increasing train speed, and the forces increased at a greater rate for the diverging route.<sup>1</sup>

Licciardello et al.<sup>2</sup> used displacement transducers to measure the vertical and lateral deflections of switch points of a 60 km/h turnout located in Italy. After gathering data for a variety of passing trains that included both freight and high-speed passenger trains, the study concluded that switch point movement does not depend on train type and is more closely linked to the angle of attack of the wheels. It should be noted that the axle loads of the freight traffic in this study were likely not as heavy as those in the USA, resulting in a more homogeneous loading situation. Little influence of the frequency of dynamic interactions on the switch points was detectable in this study.

Wiest et al.<sup>19</sup> developed a three-dimensional finite element model that accounts for elastic-plastic deformation of the frog nose and incorporates shear forces caused by the rolling wheel. Using a quasi-static model, more deformation occurred in the nose of a manganese steel frog than in the nose of a composite steel frog. The deformation of the manganese frog led to a reduction in contact forces of 20%. Additionally, damage of the nose was estimated by locating tensile principle stresses that could result in voids or cracks.

Another model focused on the impact of irregularities and gaps of a no. 38 turnout with a moveable point frog designed for HSR applications.<sup>9</sup> Multiple gaps created greater vehicle accelerations than did single gaps on the same turnout. Although the presented conclusions may seem intuitively obvious, the authors highlighted the need to minimize and

eliminate gaps on turnouts for high-speed operations and presented quantitative results to support their argument.

Unfortunately, none of the discussed research studies examined the situation of mixed traffic, HSR and HAL, which is pertinent to shared corridors in the USA. A study is currently underway at the University of Illinois at Urbana-Champaign that is comparing impact loads measured on Amtrak’s Northeast Corridor (NEC), an example of shared track operation. Initial results from this data show that greater variability exists for HAL freight impact loads than HSR impact loads. The data has not yet been analyzed with respect to train speed. Quantifying the load impacts from both traffic types on special trackwork would significantly contribute to the advancement of the field.

## **Discussion**

### *Implications for different shared operation types*

Effective design of special trackwork is necessary to make shared railway systems as efficient as possible. In order to satisfy the design requirements for special trackwork, railway engineers must understand the various types of shared rail corridors and identify the constraints that are present with each type.

The FRA classifies passenger and freight train shared operations into the following types.<sup>20</sup>

1. Shared track: where passenger and freight trains use the same trackage on single or multiple tracks for all or part of their operation.
2. Shared right of way: where passenger and freight trains use separate tracks but with adjacent track centers of 25 ft (7.6 m) or less.
3. Shared corridor: this is similar to shared right of way, but with adjacent track centers of more than 25 ft (7.6 m) but less than 200 ft (61 m) apart.

In addition, “hybrid” systems exist, in which HSR trains operate on dedicated, high-speed infrastructure on some sections and conventional infrastructure on others.

Shared track systems impose unique challenges for infrastructure design. High-speed operations require more stringent track geometry and maintenance standards, as the effect of typical geometry and track component problems can be amplified at high-speed operation, causing passenger discomfort and posing safety concerns. For freight traffic, a much more resilient system is desired to mitigate the impacts caused by HAL operation. For a shared track system, these challenges must be met simultaneously because both types of traffic must be supported by the shared track structure.

For a shared right-of-way system it is possible that special trackwork will be required to support both

track types when dedicated freight tracks must cross dedicated passenger tracks at grade, or vice versa. Since the tracks are spaced close together, it is unlikely that a diverging move for either track will be graded separated. Consequently, crossings may be required to handle HAL and HSR loading conditions.

In a shared corridor system, the issue of special trackwork is typically not applicable, as track centers for adjacent tracks can be up to 200 ft apart. Dedicated passenger lines should be graded separated when crossing a conventional line.

For a “hybrid” track system, dedicated high-speed rail equipment may operate on conventional rail networks near city centers, but for majority of the route operate on a dedicated track. This type of system creates similar challenges to shared track systems because the special trackwork must be designed to support both HAL and HSR loading conditions. However, on the shared portion of the track, the operating speed of a high-speed train will likely be reduced as it approaches a station. Consequently, there may be little incentive to design special trackwork to accommodate higher speeds.

### *Knowledge gaps and research needs*

The many gaps that exist in the current understanding of special trackwork as it relates to shared HAL and HSR operations result in a variety of research opportunities. After a vigorous review of current research, the primary needs in this field appear to be load–damage correlation, life cycle cost of upgrades and material behavior of track components.

The effects of various types of impact and dynamic loads on shared corridors are not fully understood. The damage caused by the different loading characteristics need to be analyzed in order to guide turnout geometry and materials selection. The tradeoffs between running more HAL freight traffic and the desire to increase speed through turnouts should be investigated with regard to the possible accelerated wear they cause.<sup>21</sup> Current field observations and models can be extended to create a damage index that can relate axle load, train speed and tonnage to deterioration of special trackwork components. This tool could allow track designers to select the appropriate special trackwork in a more complex loading environment than conventional railways and would allow track maintainers to strategically plan maintenance.

Many of the proposed designs and modifications to special trackwork for use in shared corridors are very theoretical in nature, or have seen only a small amount of field testing. A research need in this area is continued field experimentation and application of proposed component designs to test track segments. A better understanding of component effectiveness under realistic loading scenarios is necessary to ensure the feasibility of use in mainline service.

The development of innovative and modified track components to allow shared corridors to operate efficiently will result in improved track durability, necessitating the re-examination of many of the recommended practices for layout and maintenance.<sup>7,22</sup>

Due to the relatively new concept of running HAL and HSR on shared track, limited amounts of actual life cycle data of special trackwork under this type of train operation is available. When new components for shared corridors are designed and installed, close analysis and monitoring of wear and material behavior should be noted to produce detailed life cycle data for future designs. Little data exists on material research for specific shared corridor applications; however, it would seem that the advancement of materials in the general field of railway engineering can contribute to increased durability of special trackwork components. Research on head-hardened crossing materials and heat-treated switch point tips could result in turnout components that can achieve higher fatigue strength and experience higher lateral forces.<sup>17</sup>

Finally, applications for premium special trackwork, such as moveable point frogs and FBFs, should be investigated based on traffic and route characteristics. For some shared rail corridors in the USA, capacity and speed requirements may necessitate the use of moveable point frogs. However, many of the proposed shared corridors are being planned on lower-capacity freight routes that could operate efficiently with a more conventional frog. A model based on data from Amtrak’s NEC or European countries that operate shared corridors should be developed to help railway engineers understand the optimal thresholds for special trackwork selection.

### **Conclusions**

Special trackwork research and design has progressed mainly with a focus on increased axle loads in North America or higher speed in Europe. A review of existing research shows the need for a more integrated focus on understanding the loading characteristics and design tradeoffs required for shared HAL and HSR operations. Regardless of the strategy to improve its design, special trackwork must provide safety and durability for successful shared rail corridors.

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