HIGH-SPEED RAIL (HSR) - NEW CORRIDOR DESIGN CHALLENGES AND ALTERNATE ANALYSIS (SHARED AND/OR GREENFIELD CORRIDORS)

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ABSTRACT

This paper presents the various concepts and alternatives considered by Texas Central High-Speed Railway (TCR) and Arup to identify and evaluate potential High-Speed Rail (HSR) alignments between Houston and the Dallas/Fort Worth (D/FW) Metroplex which will accommodate speeds in excess of 200mph. The paper describes the project objectives, the initial planning process, and the identification of preliminary alternative alignments. It discusses the methodology and technology used by Arup in identifying and refining potential alignments within the Houston to D/FW corridor, in responding to the project objectives, and in giving due consideration to the dynamic characteristics of the rolling stock and systems technology.

This paper introduces TCR’s HSR project, its various technical challenges related to greenfield and shared high-speed passenger and freight rail corridors. The paper defines mitigation methodology for these challenges and describes the steps that could be taken in the planning and design process of the project and its objectives. It also takes into account the rail plan promulgated by the Texas Department of Transportation (TxDOT).
The unique milestones planned for, and challenges addressed, during the course of the project are conversed in this paper and include: minimizing the right of way (ROW) take, lowering environmental impacts, designing a dedicated, grade separated alignment, and avoiding drainage basins. Various matrices were generated to identify grade separations, structural inventory, drainage inventory, ROW purchase/parcel information, and GIS databases that will be discussed in this paper.

INTRODUCTION

Arup was commissioned to develop a decisional document by TCR to conduct preliminary engineering studies for the feasibility of a HSR corridor for operations between Houston and the D/FW Metroplex, Texas.

The object of this study was to review, analyze, plan, and begin preliminary design of the HSR line between Houston and the D/FW Metroplex making use of greenfield and/or existing freight rail corridor, utility corridor, and highway rights-of-way (ROWs) that could be used for high-speed operations. The study carefully considered the following:

- An alignment(s) that could accommodate a journey time of 90 minutes or less from a station location in Houston to a station location in the D/FW Metroplex – various stations locations were identified and are still under study;
- Optimizing the preliminary horizontal and vertical alignment(s) for the operating characteristics of the train set technology;
- Minimizing the relocation of freight tracks and impacts to freight customers, if the potential alignment(s) were to fall within one or more freight ROWs;
- Minimizing the relocation of overhead utility lines, if the potential alignment(s) were to fall within one or more utility ROWs;
- Minimizing the impact to roadways and major utilities if the alignment(s) were to fall within one or more roadway ROWs;
- Identifying the ROW required for the HSR track, stations and ancillary facilities;
- Initiating a risk matrix identifying technical and/or engineering challenges and fatal flaws, if any; and
- Developing a preliminary cost estimate based on the initial level of design for this effort.

In spite of a wide range of international experience in the industry on the planning, design, and operation of HSR lines, the USA still faces a number of challenges which primarily stem from the unique national and state environmental processes, the lack of national design guidelines and/or standards for the construction and operation of true HSR systems (generally referred to as “very high-speed rail” or “core-express” with operating speeds in excess of 180mph), and the absence of a serviceable true HSR line.

Additionally, the many planned HSR projects propose sharing existing freight, utility, and/or highway ROW or building alongside them to minimize the project’s environmental and social impact. Such a proposal triggers the need for extensive coordination with the ROW owners and operators and complicates the design and environmental review of the project.
IDENTIFICATION OF ALTERNATIVES

The development of potential HSR alignments between Houston and the D/FW Metroplex involved the study of various constraints, including that of existing development, environmentally sensitive areas, and topography. The alignments, as identified by TxDOT and shown in Figure 1, are generally located along existing transportation corridors (road or rail) in an effort to minimize adverse social and environmental impacts and to make use of prior knowledge of constraints utilized in development of existing networks which could potentially help reduce the environmental impacts. The three potential alignments identified for study were consistent with those chosen by TxDOT between Houston and D/FW Metroplex are as follows:

- Burlington Northern Santa Fe (BNSF) Teague Line.
- I-45 (greenfield alignment).
- UPRR Hempstead Line.

Arup took a high-level view of the potential alignments identified along the Houston – D/FW corridor and conducted a high-level optimizing to accommodate the operating characteristics of Central Japan Railways’ (JRC) N700-I, the international version of the N-700 Shinkansen train. Special attention was given to providing appropriate curve radii and speed, while maximizing the use of existing ROW and setting conditions to achieve the full potential of the N700-I technology for each alignment.

This technology and rolling stock was selected because of JRC’s integral role as development partner with TCR in this project. The rolling stock is currently going through a Rule of Particular Applicability (RPA) to determine what parameters have to change in its design to meet Federal Railways Administration (FRA) regulations and be permitted to operate in the US.
Figure 1 – D/FW to Houston Analysis Corridors (1)
The general approach in designing the alternative alignments is represented diagrammatically in Figure 2.

**Figure 2 – Mitigation Hierarchy (2)**

This hierarchy is widely accepted and was used consistently throughout this project. Its use has assisted in the development of alignments with an emphasis on avoiding impacts in the first instance, and minimizing or mitigating those that cannot be avoided. Residential areas were of particular concern in determining the alignment. Residual impacts would be dealt with through repair or compensation, with options investigated through further design and local engagement at the future stages of design.

Urban areas contain concentrated populations, which could be at risk of unacceptable impacts during the construction and operation of the proposed high-speed railroad. Such impacts could only be avoided by following an existing transport corridor where space allows, or by extensive tunneling at significant cost.

**Shared Corridors**

It is important to understand the definition of HSR, shared corridors, and the rolling stock performance characteristics. A shared-use railroad corridor, as defined by the FRA, is a broad term that includes three different sharing arrangements (3);

- Shared track; where there are no dedicated tracks for different traffic types,
• Shared right-of-way; dedicated tracks where two rail services operate on separate parallel tracks having a track centerline separation less than 25 feet,
• Shared corridors; dedicated tracks where track centerline separation is between 25 and 200 feet.

High Speed Rail (HSR)
The term HSR has been used very loosely in the USA, and has been perceived differently based on the familiarity of the audience and the context in which it is used. FRA’s HSR strategic plan divides potential operations into the following four broad categories:
• HSR – Express: top speeds of at least 150 mph
• HSR – Regional: top speeds of 110–150 mph
• Emerging HSR: top speeds of 80–110 mph
• Conventional Rail: top speeds of less than 80 mph

Whereas the HSR system being considered by TCR comprises of the following characteristics:
• Trains designed for sustained operation at or above 180mph
• Trains with limited stops that provide service between population centers or urbanized areas
• Grade-separated crossings with other transportation systems (roads, rail, etc.)
• Dedicated and sealed tracks.

Use of Freight Rail ROW
The use of freight rail ROW can be either very straightforward or very complicated. On average, freight ROWs are around 100ft wide for a single or dual track alignment.

The vertical curve criteria of freight trains are somewhat similar to that of HSR trains, where steep gradients are avoided by both HSR and freight operators. For horizontal curves, freight ROWs tend to have curves in the 1000ft to 3000ft radii range (from around 6º to around 2º degrees of curvature), which is too tight for HSR operating at speeds greater than 120 mph.

Additionally, guidelines have not yet been established for the separation distances between HSR tracks and freight tracks, either here in the USA or elsewhere.

Alternatives Summary
1)  **BNSF Teague Line Alignment**

Early work on this potential HSR alignment attempted to utilize existing freight and/or highway ROW. The analysis of the BNSF Teague Line alignment determined that the proposed alignment would need to be straightened over significant lengths to achieve the desired HSR operating characteristics, thereby requiring significant deviations from the existing ROW. However, there were no fatal flaws identified in the development of this HSR alignment. Various alignment alternatives were developed between the station locations in Houston to D/FW along this corridor.
2) **I-45 Alignment**

TxDOT identified the I-45 alignment as a “greenfield” corridor even though significant portions of the I-45 corridor have been well developed.

The goal of the I-45 alignment was to stay within the existing interstate corridor as much as possible. The HSR alignment frequently goes beyond the confines of the 200 feet I-45 corridor to ensure the existing access to the local roadway network. Additionally, the curvature – both horizontal and vertical – of the I-45 corridor was designed to accommodate automobile and freight truck speed characteristics and thus is too constrained to allow for the full-speed operation of a high-speed passenger train. The potential impacts to numerous local and regional roadways that intersect the HSR alignment could be minimized by elevated railway structures, but these pose significant logistical and technical challenges during construction.

3) **UPRR Hempstead Alignment**

The goal of the UPRR Hempstead alignment alternative was to follow the existing UPRR Hempstead corridor from Houston to the D/FW Metroplex. Like the BNSF Teague alignment, this alignment will need to be straightened over significant lengths to meet the desired HSR operating characteristics, thereby requiring significant deviations from the existing ROW. However, there were no fatal flaws identified in the development of this HSR alignment.

**Key Issues**

Following are the key issues identified for all the alignment sections between Houston and D/FW corridor during the preliminary study;

- Local road closures and maintaining land access
- ROW acquisition
- Longitudinal utility relocations and access requirements in shared corridor (gas, telecoms, electrical)
- Utility crossings
- Relocation and/or service continuation to major customers along the freight rail corridor
- Maintenance and protection of traffic
- Design and construction processes and phasing to minimize impact to roadways.
- Environmental approval to cross reservoirs and water bodies

**PRELIMINARY ENGINEERING**

Once the alternative alignment analysis was completed, preliminary engineering of the selected alternatives was carried out keeping in mind the goals and objective of the project. Following are the key tasks that were carried out at various stages of the initial study along with the approach taken to carry out each individual task.

**Task 1 – Project Definition Document**

A Design Criteria Document was developed as a set of general guidelines and specific criteria to be employed in the planning, design, and construction of the new HSR system and associated infrastructure. The design criteria is based on the operating characteristics of the JRC N700-I rolling stock.

The Design Criteria Document is a living document that will continue to develop as the design advances and will be critical in defining the objectives at each stage of the project.
Task 2 – Route Survey and Alignment
A wide range of geospatial data was collected and converted into useful electronic formats and mapping products. This geospatial data facilitated the analysis of various elements of the preliminary design and was particularly critical to informing the following:

- HSR alignment alternative analysis and selection
- HSR facility locations
- Land parcel registry
- Geotechnical study
- Drainage design and flood risk study

Aerial imagery along with digital terrain map data of the corridor was procured. After multiple iterations and alternatives analyses, optimal baseline alignments were identified within each of the corridors under consideration for this project. These baselines improve the overall feasibility of the alignments as they pertain to environmental, operational, and urban constraints.

The primary deliverables of the GIS-based analysis included parcels, hydrology, route maps, and several other genres of maps and graphics that were used in reports and presentations.

The alignments produced sought to avoid:

- Tight curves in constrained areas,
- Multiple grade crossings in urban areas,
- Major highway crossings,
- Power lines, and
- Potential environmental impacts due to various water bodies along the route.

Task 3 – Grade Separations and Structures
The potential HSR alignments cross a number of existing highways and other roads. In most cases, the team discovered that it is more cost-effective to carry a roadway over the HSR alignment rather than carry the railway over a roadway. However, there are locations where taking the HSR alignment over the roadway can be the better option, due to potential impacts to road traffic, construction schedule, and cost, particularly when more than one roadway is involved.

Careful consideration was given to identifying structure types that are both structurally capable and economical, while leaving room for future aesthetic considerations. Many types of structures are required to implement the project, including HSR bridges, freight rail bridges, highway and roadway bridges, crash walls, retaining walls, noise walls, and fences. Typical economical designs were developed for each type of structures, so they could be used throughout the corridors.

The proposed HSR bridges are generally viaducts that carry the high-speed trains over waterways, flood plains, and freight railway and roadway crossings.

Several complex intersections/interchanges were analyzed in detail to fully understand the requirements of both road-over-rail and rail-over-road options. Impacts to the existing bridge
structures and the freight tracks were avoided where possible. Where the HSR alignment remains at-grade, road bridges were identified to carry streets and highways across the alignment. Design and construction of new road bridges were based on TxDOT standards.

A set of recommendations were developed by evaluating the grade crossings against the following set of general guidelines:

- Reduce and/or eliminate impact to adjacent properties and/or farmland, hence, minimize any land acquisition needs.
- Provide alternate access to residential and commercial properties impacted by the proposed alignment.
- Maintain access for emergency vehicles at all proposed grade separations.
- Maintain minimum vertical and horizontal clearances at existing bridges over the proposed HSR.
- Provide alternate access for local traffic within a reasonable distance for all proposed road closures.

The size and locations of noise walls, crash walls, and retaining walls were based on site constraints and design criteria assumptions.

**Task 4 – Drainage Structures and Assessment of Flood Maps**

Arup studied the hydrology, flood zones, and other stormwater-related sensitive natural resources along the potential HSR corridors to enable informed decisions regarding the design of the alignment, stations, and ancillary facilities.

Significant gaps were discovered in existing publicly available flood mapping data. To address these gaps, Arup developed preliminary flood delineation studies in critical areas of the alignments. Where flood zones were known or delineated, encroachment of the proposed HSR alignments was minimized by the selection of the appropriate horizontal alignment or by elevating above flood zones with viaduct bridges. Hydrology data was compiled and developed and has been integrated into a GIS geodatabase.

The drainage design for the proposed HSR alignment included preliminary identification and sizing of stormwater quality and quantity control measures to manage flooding risk, pollution risk, and increased flows associated with the alignments. This is necessary to ensure the continual and safe running operation of trains by controlling track flooding and maintaining the required track bed conditions.

**Task 5 – Geotechnical Desk Study**

As part of the geotechnical services an initial windshield survey was conducted to establish preliminary ground conditions based on a review of publicly-available geological maps, historical maps, aerial and satellite maps, and previous ground investigation records.

A matrix of findings was generated for future development; however, one of the principle findings was that the alignments lie on generally soft/expansive soils that are typical of central Texas, and there will be locations where the soils will need to be replaced with suitable fill. Site-specific ground investigations will be required in future design phases. For costing purposes, however, pile foundations were used for all the structures.
Task 6 – Station Footprint Assessment and Location Study

A preliminary footprint estimate for each of the proposed HSR line passenger stations was developed. The footprints account for the boarding platforms, in-station tracks, approach tracks and switches, and motor vehicle parking garages. At this level of design, a level of service, architectural design, and building construction materials comparable to an international airport environment were assumed.

The study of alternative station locations is being advanced separately from the alignment study but in close coordination with an investment grade ridership study. The results of the station studies will be incorporated into future design stages.

For purposes of this report, TCR considered four general potential areas for its HSR passenger stations: 1) Downtown Houston, 2) Suburban Houston, 3) Downtown Dallas, and 4) Suburban Dallas. At this stage no station locations have been selected. The criteria for station selection, in part, will include

- Intermodal Connectivity
- Highway Access
- Land Availability
- Existing Land Use

Intermodal Connectivity

It is anticipated that for optimum integration, HSR station locations will maximize connectivity to both existing and planned public transit systems. These public transit systems will generally comprise of bus, bus rapid transit, commuter rail, paratransit and light rail systems. Bus systems could face little technical difficulties in their integration, with the stations being designed to accommodate bus lanes, waiting areas, etc.

Over time, light rail systems will be integrated where the HSR station locations are on existing light rail networks. Where the station location is not on an existing light rail, negotiations could be made with the operator of the systems to extend into the station either during HSR construction or at a later date.

Highway Access

Mobility in both rural and urban areas of the Texas is primarily dependent upon personal vehicle transportation on the state federal and local highways with only limited access to mass transit systems. The main highway systems are thus seen as feeder systems to the HSR. Ample parking for HSR passengers with provision for rental car facilities are considered for the stations and car parking areas.

Land Availability and Existing Land Use

Currently underdeveloped or commercial land is particularly desirable for station locations to minimize disruptions to residential neighborhoods. Further study and consultation with local stakeholders is required in future design phases to update and refine the design, as well as to account for site-specific opportunities and constraints.

Task 7 – Yards and Shops Planning

Preliminary footprints were developed for the yards and shops required to maintain the rolling stock tracks, structures, systems, and for the storage of rolling stock. The configuration of the
rolling stock has not been finalized, however for planning purposes we have assumed an eight car consist with a length of approximately 215m.

Early planning calls for a Heavy Maintenance Facility (HMF), a Light Maintenance Facility (LMF), and two additional Maintenance of Way (MOW) Facilities to be located along the alignments to provide full coverage for the entire HSR corridor.

Task 8 – Systems

Base requirements for the major components of the systems, including traction power, automatic train control (signals), communications, and land sizes needed for these systems were identified.

At this stage of the design only space requirements were assessed along the HSR ROWs. Future design phases will integrate the JRC systems into the alignment design. Additional studies will be conducted to investigate the Traction Power requirements of the HSR.

Task 9 – Risk and Opportunities Workshop

Risk management processes reflecting the risks and opportunities were analyzed. Some identified risks were mitigated during the initial design phase, while other risks were added as more details arose. This process is typical and reflects the dynamic nature of the risk management process through the life of the project.

Table 1 presents the rating system that was established to determine the severity of risks from the following impacts:

- Probability Impact
- Cost Impact
- Schedule Impact

TABLE 1 – Risk Impact Scoring Matrix

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability Impact</td>
<td>&lt; 10%</td>
<td>11% - 35%</td>
<td>36% - 64%</td>
<td>65% - 89%</td>
<td>90% - 99%</td>
</tr>
<tr>
<td>Cost Impact</td>
<td>$10,000 - $100,000</td>
<td>$100,000 - $1 Mill.</td>
<td>$1 Mill. - $10 Mill.</td>
<td>$10 Mill. - $100 Mill.</td>
<td>&gt; $100 Mill.</td>
</tr>
<tr>
<td>Schedule Impact</td>
<td>Days</td>
<td>Weeks</td>
<td>1 to 3 Months</td>
<td>3 to 12 Months</td>
<td>&gt; 12 Months</td>
</tr>
</tbody>
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The risk rating for any perceived risk is calculated by the following Equation.

\[
\text{Risk Rating} = \text{Probability Impact} \times (\text{Cost Impact} + \text{Schedule Impact})
\]

This resulted in a wide range of Risk Ratings identified during this initial design. The risks were then further categorized based on severity as being Low, Moderate, High, and very high by the
project team. Here are few examples of some very high risks categories identified during the preliminary analysis;

- Strategy for longitudinal utility relocations (gas, telecoms, electrical),
- Permanent road closure candidates,
- Land acquisition beyond existing (freight rail, highway) ROW.

**Task 10 – Environmental**

Early in the conceptual design process, a fatal flaw analysis of the alignment was carried out to identify potential environmental risks associated with various corridors. This analysis included desktop collection and analysis of publicly available environmental data including but not limited to the following sources:

- U.S. Fish and Wildlife Service (USFWS) listed species by county and by state reports,
- Texas Parks and Wildlife Department (TPWD) annotated list of rare species by county,
- USFWS Critical Habitat Portal,
- USFWS National Wetlands Inventory (NWI) maps,
- U.S. Geological Survey (USGS) National Hydrography Dataset (NHD),
- USGS National Land Cover Dataset (NLCD); and
- USGS topographic maps.

**Socio Economic and Environmental Justice Impacts**

- Historic and Native Indian impacts A 1,000-foot-wide buffer zone was centered on the potential alignments to encompass potential issues and constraints associated with any minor deviations that may occur from a proposed preferred alignment. The resource issues addressed in this analysis include:
  - Protected species, specifically state and federally listed threatened or endangered plant and wildlife species;
  - Wetlands and water bodies, particularly waters of the US as defined under the Clean Water Act Section 404 waters and Rivers and Harbors Act Section 10 waters; and
  - Land use, with an emphasis on highly populated areas, environmental justice constraints and public land.

Based on the desktop analysis, no fatal flaws were identified that would prevent the successful completion of the HSR project. Several impacts were identified; however, these can all be avoided and/or mitigated.

**TECHNICAL CHALLENGES AND SAFETY IMPROVEMENTS**

Having clearly defined goals and objectives is critical to the successful implementation of this HSR project. This helps mitigate the potential issues at earlier stages of planning and/or design. Grade and bridge crossings, as well as ROW constraints and land acquisition has already been discussed above.
Other technical challenges were also considered, and include:

- Utility Relocations;
- Minimizing the Impact of Derailments
- Identification of HSR Ballast Flight Risk Factors and Risk Mitigation Strategies
- Environmental Issues including High-Speed Rail (HSR) Running through Town Centers.

**Utility Relocations**

Utility work will need to be completed at many of the crossings and along the corridor to accommodate the new HSR track and road realignment. Utility relocation and coordination is particularly challenging to execute in areas of high tension overhead electric lines and unidentified buried utility lines.

**Minimizing the Impact of Derailments**

The most frequent cause of accidents in HSR operations has been foreign (non-railroad) obstructions on the ROW. The remaining causes are most often related to equipment malfunctions attributed to flaws in the engineering and/or construction phases of developing rolling stock or infrastructure. Guidelines for derailment mitigation and track fouling measures, including track separation, crash walls, etc. have not been developed.

**Identification of HSR Ballast Flight Risk Factors and Risk Mitigation Strategies**

An important technical challenge identified at this stage of design is the potential displacement of ballast on ballasted HSR tracks due to the aerodynamic forces from very high speed trains. Possible consequences identified are:

- Void creation on ballast bed
- Damage on railhead and train
- Potential damage to adjacent surroundings

Since the HSR alignment is designed for speeds higher than 180 mph it will require mitigation strategies to avoid risk of ballast flight. Following are some potential mitigation measures identified by researchers that can be adopted later on (4)

- Aerodynamic sleeper
- Lowering of ballast height (a measure implemented in France and Italy as well)

**Environmental Issues**

Some of the key environmental issues include:

- Previously Contaminated Soil and Groundwater – While this is certainly a key issue related to construction, this has not yet been studied.
- Lead and Asbestos Containing Material Mitigation – The scope of work may involve demolition of residences and commercial buildings. Older buildings can contain asbestos materials and lead paint. Mitigation for construction worker exposure and disposal will be necessary.
• Wetland Impacts – Designers are aware of the fact that there will be some need for wetland delineation and the mitigation of subsequent impact commitments required in the final Record of Decision (ROD) documents for any of the potential corridors.
• Storm Water Pollution Prevention – Designers are familiar with these requirements and have initiated coordination with regulatory entities that govern affected jurisdictions to obtain the necessary permits.

Many of these design challenges have been identified to a preliminary design level, but a more detailed analysis be conducted during the environmental process.

OTHER MODES OF TRANSPORTATION AND HSR BENEFITS

Analyses of air and automobile alternatives to HSR have resulted in HSR being superior to the other modes of transportation in terms of time, safety, and reliability. HSR alleviates highway and airport congestion, pollution, energy consumption and most of all; this project will provide a safe transportation service between Houston and the D/FW Metroplex.

With respect to highway congestion relief, the HSR will have a growing positive impact as I-45 is travelled more with the growing population of Texas. HSR will quickly become even more cost effective and time efficient, compared to driving. HSR can significantly decrease the door-to-door commute times when compared to air travel and it is likely that a significant share of air travelers will want to switch to HSR. Additionally, HSR provides value in providing travelers with a choice of transit modes and creates local employment opportunities in planning, design, and construction.

CONCLUSIONS

The objectives of the TCR HSR project were successfully accomplished by completing the following:

• Creation of a project definition document – this document included the preliminary operating plan, service and functional requirements, and design criteria. This document will evolve throughout the design process.
• Completion of an initial route survey and alignment study to understand potential high-speed alignments, based upon minimizing or eliminating the relocation of the existing structures including local roads, road bridges, and freight tracks along the route. Where existing infrastructure could not be relocated, the HSR was grade separated.
• Initial drainage and hydrology surveys, analysis and assessment of flood maps, and geotechnical analyses were completed and the results were used to refine the alignment and track design.
• Assembly of preliminary inventories of track elements, to include the at-grade sections, rail and roadway structures and viaducts, grade crossing separations, earthworks, and other important track elements.
• Identification of potential stations, yards, shops and substation footprints after the planning processes.
• Identification of a risk and opportunities register with no fatal flaws identified. This will continue to be a living document throughout the implementation process.
• Development of an Environmental Permits and Approvals Roadmap.
• Compilation of a robust preliminary cost estimate.

Having completed all the tasks for the initial stages of preliminary design, the following set of key conclusions is reached:

• In general no technical or engineering fatal flaws were identified in the analysis of each of the rail corridors.
• Journey time of less than 90 minutes can be achieved on the potential alignments between Houston and D/FW Metroplex.
• Effective utilization of the existing ROW varies for various alignments.
• The environmental roadmap results indicate that there are no environmental fatal flaws to the project. The potential of impacts to water crossings, endangered species, native habitat, and environmental justice constraints will need further investigation and analysis to be addressed in the environmental permitting process.
• The largest cost to the project tends towards railway structures, providing opportunities to value engineer the design in detailed design phase.
• Grade separations will greatly increase safety and improve access for the communities along both the freight rail and highway corridors. While a large project, it is relatively straight-forward from a technical perspective, and suitable for the deployment of JRC’s N700-I system.

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FIGURES AND TABLES
Figures
Figure 1 – D/FW to Houston Analysis Corridors
Figure 2 – Mitigation Hierarchy
Tables
Table 1 – Risk Impact Scoring Matrix