ERRATA to:
Cost Savings through Innovation
Eagle P3 Project, Regional Transportation District, Denver, CO
by Rik Lor, P.E. and Scott Henning, P.E.

The AREMA Manual for Railway Engineering recommended values for impact only consider ballast and open deck steel structures and concrete ballast deck structure. AREMA does not suggest using a 200% impact factor for all structures with the rail fixed directly to the deck. An impact factor of 200% is recommended for the design of reinforced concrete slab track systems on ground. This factor recognizes the challenges created by impulse loadings with minimal dampening in this application. Bridge spans provide greater dampening and distribution of loading. Therefore lower impact factors are appropriate for concrete decks with direct fixation on most bridges. The dampening provided is directly related to length. The dampening provided by short spans may warrant a higher impact. An appropriate analysis for the impact for direct fixation of rail on a bridge would depend on the system used to attenuate impulse loading and would only apply to the members directly supporting the rail.

The AREMA Manual for Railway Engineering is a consensus based document and not a code. The impact factors presented in this paper may be acceptable in certain cases where wheels and rails can be maintained to a high level. The impact factors recommended by the Manual for Railway Engineering were created to prevent the over stressing of structural members due to wheel and rail irregularities. These irregularities such as corrugated rail, mismatched rail joints and flat wheels are not limited to freight railroad. Using impact factors from other sources than AREMA with the allowable stresses recommended in AREMA may result in over stressing structural members.

The authors are correct in stating “Applying the AREMA bridge live load impact equations to the Eagle Project concrete bridges would have yielded impact factors between approximately 20% and 32%.” These are what AREMA recommends. The AREMA impact equations for concrete or for steel in the 50 to 130 foot range are less that the ACI impact factor presented in the paper based on the assumed constant frequency. For concrete spans greater than 130 feet AREMA recommends 20%. The authors do not state exactly what impact factors were used for this project. In the abstract and the presentation, the authors state that their research showed that impact factors of 10-15% range may be used. The reduced impact would likely create a minimal reduction in bridge cost. The authors state that the estimated savings was $2 million on a $2.2 billion project. The 0.1% reduction in project cost supports this idea.

Prepared by H. C. Swanson, PE, SE, AREMA Group Vice President - Structures – November 20, 2014
Cost Savings through Innovation
Eagle P3 Project, Regional Transportation District, Denver, CO

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by

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ABSTRACT

The Eagle Project, conducted by the Denver Regional Transportation District (RTD) with the concessionaire team Denver Transit Partners (DTP), is a public-private-partnership (P3) to include the design, construction, financing, operation, and maintenance of track, vehicle, and associated infrastructure for commuter rail lines in Denver, CO. The $2.2 billion capital project, comprised of federal funds, RTD sales tax bonds, and private equity from the concessionaire team, will connect downtown Denver to Denver International Airport to the east, Wheat Ridge to the west, and Westminster to the north using 36-miles of new 25kV electrified commuter rail (effectively doubling RTD’s existing system). It also includes 14 stations and a new commuter rail maintenance facility (CRMF).

This paper will discuss the advantages gained by RTD through utilization of the P3 model. RTD has experienced both cost savings and schedule acceleration by encouraging and accepting the innovation brought to the Eagle Project by the DTP concessionaire team. Simultaneously, risk to RTD continues to be mitigated by the 28-year ownership and maintenance aspect of the project execution.

Included herein is specific discussion of the innovation surrounding the live load impact factor used to design direct fixation bridges on the Eagle Project. The RTD-DTP concessionaire contract tasked the design team to investigate this design parameter. The design team’s research, including the use of ACI-358.1R-92 and finite element modeling of the structures, showed that impact factors in the 10-15% range may be used. This differs significantly from the AREMA recommendation of 200%. Use of this lesser impact factor economized RTD direct fixation bridge design and construction and exemplifies the benefit of incorporating the expertise of a concessionaire.
INTRODUCTION

As a result of the current recession, many public transit agencies across the United States face increasing budgetary challenges. Many transit agencies have cut service, raised fares, put off routine maintenance, and stopped building new capital infrastructure among other actions. According to a national survey taken by APTA in 2011, “85 percent of agencies reported flat or decreased capital funding.”

As the Regional Transportation District (RTD) looked to build new transit infrastructure around Denver, Colorado, the investigation and implementation of innovative procurement options became essential. After an extensive review, RTD staff recommended RTD utilize the public-private partnership (P3) delivery method to build the Eagle Project.

In August 2007, the Eagle Project was approved by the FTA to participate in their Public-Private Partnership Pilot Program (Penta-P) under New Starts. RTD received permission from the FTA to enter Preliminary Engineering in 2009 and to enter Final Design and Construction in 2010. Revenue service is scheduled to begin in 2016.

This paper discusses how RTD leveraged the P3 contract partnership to save construction cost by encouraging and accepting the innovation brought to the Eagle Project by the Denver Transit Partners (DTP) concessionaire team.

EAGLE PROJECT OVERVIEW

FasTracks is RTD’s voter-approved transit expansion program to build 122 miles of commuter rail and light rail, 18 miles of bus rapid transit service, add 21,000 new parking spaces, redevelop Denver Union Station, and redirect bus service to better connect the eight-county District within the metropolitan Denver region.

A substantial component of FasTracks is the $2.2 billion “Eagle Project”. The Eagle Project includes the design, build, finance, operate and maintain phases of three commuter rail lines, a new maintenance facility, and the new electric multiple unit (EMU) rolling stock (see Figure 1). The main four components that make up the Eagle Project are:

- The East Rail Line: A 22.8-mile electric commuter rail transit line that runs from Denver Union Station to Denver International Airport. Five intermediate stations were initially included with this line.

- The Gold Line: An 11.2-mile electric commuter rail transit line to Denver’s west that will connect Union Station to Wheat Ridge, passing through northwest Denver, Adams County, and Arvada. Eight stations are to be constructed as part of the Gold Line.

- The Northwest Rail Line: A 41-mile high-capacity, fixed-guideway transit project from Denver Union Station to Longmont, passing through North Denver, Adams County, Westminster, Broomfield, Louisville, and Boulder. The first 6.2-mile segment of the Northwest Rail Line from Denver Union Station to south Westminster will be constructed as part of the Eagle Project.

- The Commuter Rail Maintenance Facility: The site to repair, clean, and store the vehicles that will serve the Eagle Project commuter rail lines and a future North Metro Rail Line.
In 2010, RTD entered into a 34-year design-build-finance-operate-maintain lease agreement with a concessionaire, Denver Transit Partners (DTP), a partnership between Fluor Enterprise, Inc. and Macquarie Capital Group Ltd. over which time RTD will make payments for construction and service performance limited by an affordability level. 10.9 percent (or $240M) of the capital cost is being financed by the Concessionaire using a combination of equity participation and private-sector debt mechanisms. Since obtaining its approval to participate in the FTA’s Penta-P, RTD has finalized design and completed 56 percent of the construction.

The Eagle Project Delivery Approach

Project delivery methods generally fall under the categorization of a design-bid-build or design-build.

Traditional design-bid-build delivery method requires the project sponsor to seek out designers and contractors separately while retaining all interface responsibility. The work proceeds in a linear fashion, with design being completed prior to the procurement of a contractor. The linearity of project task completion generally increases project duration significantly, as no work begins before design is completed in its entirety. Meanwhile, design-bid-build also requires the project sponsor to provide direct oversight to all contractors, thus retaining all but lower level construction risk.

Conversely, the design-build approach is formatted to decrease project duration and allow for collaboration and innovation. Following release of baseline project data, the project sponsor evaluates bids from teams comprised of a contractor and designer. Bids are typically evaluated on a best-value basis, rather than strictly on price. This enables the designer and contractor to mesh ideas in order to develop a project delivery that is cost-effective, high quality, and can be built in an accelerated fashion. Upon being awarded the project, the design-builder has full responsibility for delivery of the design and construction of the project. The combination of design and construction services into one procurement process allows for site preparation and construction to begin prior to final design, thus reducing project duration. Additionally, risk to the project sponsor is reduced as they generally retain only funding, operations and maintenance, and some project development and integration risks.

Public-Private-Partnership (P3)

A P3 team is comprised of the traditional design-build team of a contractor and engineer with the addition of a financing source. Under this delivery approach, the project sponsor contracts with a single entity (a
concessionaire) to design, build, finance, operate and maintain a project over and extended term.

During procurement of a P3, the public sponsor advertising the project evaluates not only the technical proposal of the bidding teams, but also the teams’ ability to provide critical funding to the project. The financing aspect of the P3 enables government agencies to deliver projects that were previously unable to be funded.

The concessionaire represents a team of experts specializing in delivery and execution of the specific project. By partnering with this expert team, the public entity is able to deliver the project at maximum levels of economy, safety, accelerated schedule, and long term durability. Similar to the cost and schedule benefits gained by shifting from design-bid-build to design-build, the P3 enables the concessionaire to act not only as the design-build team, but as the owner as well. This directly results in a reduced project oversight responsibility on the part of project sponsor. Likewise, the project sponsor benefits through cost savings, risk allocation, and risk mitigation by passing ownership responsibilities to the concessionaire. The successful implementation of a P3 is dependent on how risk is assessed and either retained by the project sponsor or transferred to the concessionaire. The party best suited to deal with each specific risk should retain that risk in order to maximize overall cost savings.

Similarly, the concessionaire is able to capitalize on cost and schedule savings discovered throughout the project implementation. This can be through economized design and construction or through Concessionaire Proposed Changes (CPC). Using a CPC, the design-build team can propose changes to the initial bid design. If approved by the project sponsor, both the concessionaire and project sponsor share in any cost savings. Hence, while the concessionaire must deliver a quality system, it is incentivized to save money through innovative design and construction delivery.

RTD utilized the P3 model to deliver Eagle Project and on July 9, 2010, awarded the project to Denver Transit Partners. In addition to designing, constructing, and aiding in funding the Eagle Project, DTP will operate and maintain the system for 28 years past the first date of revenue service.

Development and Procurement Phases

As with all projects, the greatest level of project uncertainty is during development phase. However, the development phase is also the most opportune time to resolve uncertainty in ways that can reduce or eliminate future risk. To address project risks, RTD developed white papers to investigate specific risks and allocate them to the party best equipped to mitigate each risk. Only after the project had been defined and the majority of risks were properly allocated did RTD move into procurement.

In the procurement phase, the primary elements of risk sharing and risk transfer between RTD and the concessionaire were carefully crafted into the RFP documents. In general, risk was not accepted by RTD. With the exception of responsibilities more properly handled by a public entity, such as right of way acquisition, the majority of the risks and responsibilities allocated to RTD were transferred to DTP through inclusion of contingency to the project budget.

A key element associated with the assumption of risk by the concessionaire is the overall duration of the Concession Agreement. The duration must be long enough to truly transfer ownership risks to the private operator, but not so long that the project sponsor becomes locked into a contract with potential to become economically unattractive. Another important clause in the Eagle Project Concessionaire Agreement scales payments based on an availability ratio; if the transit system under performs, up to 20 percent of RTD’s monthly payments to the concessionaire may be withheld.

Such requirements create incentive for the concessionaire to deliver a quality system with minimal expected maintenance outages. Likewise, the potential to save in schedule and overall cost using innovative design and construction methods motivates the concessionaire to continuously identify areas
for creative designs and efficient delivery. Hence, RTD has leveraged the concessionaire’s expertise and authority to accept risk by encouraging innovation at various project stages. All-the-while, delivery of a quality system, plus a share in realized cost savings, is ensured by contract requirements and performance incentives and requirements.

By leveraging the advantages gained from utilizing the landmark P3 delivery structure and a “best-value” bid evaluation, the Eagle Project was awarded to DTP at a price $305 million under the original RTD estimated budget.

Implementation (and Operation) Phase

The implementation phase consists of DTP completing the project design, construction, and commissioning up until the start of revenue service. During this phase, RTD’s role is to focus on contract management, oversight of performance risk, and verification that the Concessionaire fulfills its commitments under the Concession Agreement. Successful implementation mandates that RTD’s risk management approach perform its responsibility to monitor DTP’s progress with regard to performance risk and contract compliance.

To assure that RTD’s role is performed consistent with the risk allocation in the Concession Agreement, a contract oversight plan and procedure was developed to provide guidance for contract management and technical oversight activity. The procedure’s intent is to avoid RTD re-acquiring risk by micro-managing the Concessionaire’s responsibilities. This proper level of project oversight is essential to project delivery success and to fully capitalize on the advantages leveraged by the P3 approach. By establishing oversight of contract compliance, rather than overseeing the methodologies used toward accomplishing contract requirements, RTD allowed DTP to economize its delivery.

The Eagle Project Concession Agreement contains both incentive and requirement for design innovation. One such example surrounds the design of the direct-fixation commuter rail (CRT) bridges. RTD identified potential for design innovation regarding the live load dynamic impact factor used for the bridge design.

Dynamic impact factor represents an increase in vertical load caused by a vehicle as a result of small vertical movements included in its passage across a bridge. For highway, light rail, and ballasted freight rail, equations exist to determine the impact factor for a specific bridge. These equations show impact factor to be an inverse function of bridge length. As a general rule, impact factor will increase as bridge length decreases. Common values of impact factor are in the range of 30%.

However, no such equation exists within AREMA for dynamic impact on direct fixation bridges. For any direct fixation structure, AREMA suggests using a 200% impact factor. Within the AREMA Guidelines, this value is not complimented by explanation as to how it was derived. Having identified this as a risk best mitigated by its concessionaire, compounded with the possibility for innovation and cost savings, RTD charged the concessionaire with performing analysis to determine the appropriate dynamic impact factor to be used in design of the Eagle Project CRT bridges.

Concessionaire Implementation

The Concessionaire shared RTD’s recognition that great potential for savings existed in the opportunity to economize the dynamic impact factor used to design direct fixation bridges on the Eagle Project. In combination with the relatively light transit loads, bridges with greater span lengths and shallower structure depth could now be designed. This would allow not only material savings, but invaluable flexibility in navigating project geometric pinch points. The Concessionaire believed an extensive study to economize the impact factor would yield substantial cost and schedule benefit.
AREMA Code Investigation

The concessionaire quickly diagnosed the excessive conservatism that would occur if dynamic impact factors from AREMA were used. Reasoning for the conservatism was based on several aspects of the AREMA code not directly applicable to the Eagle Project.

First, AREMA live load impact factors for bridge design are developed for use in freight rail design and are recommended for use on ballasted deck and open deck structures. Recent test data suggests that measured impact values are generally lower by a significant amount relative to AREMA impact factor equation predictions1.

The AREMA manual for railway engineering does not provide direction on live load impact factors for direct fixation bridges. The impact factor equations in Chapter 8 (Concrete Structures) of the manual are recommended for use on ballast deck structures. The equations in Chapter 15 (Steel Structures) are recommended for open deck bridges. Open decks are ballast-less bridges on which timber ties rest directly on longitudinal beams or stringers. Figure 2 shows AREMA-calculated impact factor relative to span length for concrete and steel bridges. Applying the AREMA bridge live load impact equations to the Eagle Project concrete bridges would have yielded impact factors between approximately 20% and 32%.

Direct fixation track impact factor is referenced only once in the AREMA manual in Chapter 8, Part 27. An impact factor of 200% for continuously reinforced concrete slab track is recommended. The concessionaire determined 200% to be very conservative for use on direct fixation bridges because slab track is much stiffer than a bridge superstructure due to continuous soil support.

The commentary for AREMA Chapter 8, Part 27 states that the 200% impact is due to the dynamic effect of rail and wheel irregularities. Impact loads due to wheel and rail irregularities have a much greater effect on stiff elements, such as slab track. The Concessionaire also determined the effect of wheel and rail irregularities will be mitigated on the Eagle Project. This would occur because of the stringent maintenance to take place during Eagle Project operations, which is geared toward rider comfort unlike a freight rail system. Additionally, continuous welded rail and the absence of turnouts on any DF bridges support the expectation of a reduced degree of wheel and rail degradation on Eagle Project DF structures.

ACI-358 Implementation

To determine the appropriate dynamic impact factor for use on the Eagle Project, the Concessionaire turned to ACI-358. ACI-358 defines impact as a function of both vehicle crossing frequency and structure natural frequency. This differs from AREMA’s ballasted track impact factor equations, which depend only on span length. ACI-358 also includes equations for simple and continuous span structures. These recognize that continuous span action yields a lesser dynamic response than does simple span action. The ACI-358 equations for dynamic load impact are shown below in Table 1.
The given lower limits for dynamic impact factor are 10% for continuous welded rail and 30% for jointed rail. The difference between these lower limits again demonstrates the large contribution to dynamic structure load caused by uneven joints in rails.

Utilization of ACI-358 came under careful scrutiny by both the Concessionaire and RTD. DTP gained confidence in its applicability given the similarities between the transit vehicles covered in ACI-358 and those used on the Eagle Project.

<table>
<thead>
<tr>
<th>Table 1: ACI 358 Dynamic Load Allowance (Impact)³</th>
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<tbody>
<tr>
<td><strong>Structure Types</strong></td>
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<tr>
<td>Simple-span structures,</td>
</tr>
<tr>
<td>Continuous-span structures,</td>
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</tbody>
</table>

**Definition of terms:**

$VCF = \text{Vehicle Crossing Frequency, Hz where,}$

$$VCF = \frac{\text{vehicle speed, ft/s (m/s)}}{\text{span length, ft (m)}}$$

$f_1 = \text{first node flexural (natural) frequency of the guideway where,}$

$$f_1 = \frac{\pi}{2l^2} \sqrt{\frac{E_c I_g}{M}}$$

where,

$l = \text{span length, center to center of supports, in. (m)}$

$M = \text{mass per unit length of the guide, which includes all the sustained loads the beam carries including its own mass, lb/in-sec^2/in. (kg/m)}$

$E_c = \text{modulus of elasticity of the guideway, psi (Pa)}$

$I_g = \text{moment of inertia of uncracked section of the guideway, in}^4 \text{ (m}^4)$
Initially wary of ACI-358's applicability to the Eagle Project, RTD requested the ACI-358 committee be contacted for input. In response, the committee did not voice any concern as to the impact factor equations and their use on the Eagle Project.

**Further Research and Support**

The Concessionaire extended its due diligence to researching the impact factors used across the rail transit industry. Eurocode became a resource because many countries base their rail bridge impact factor computations on the Eurocode equations. The Concessionaire found that Eurocode does not distinguish between ballasted deck and direct fixation bridges. Like the AREMA equations, Eurocode impact factor is inversely proportional to span length. There are two Eurocode impact factor equations: one for “carefully maintained track” and one for “track with standard maintenance”. These separate equations for maintenance standard again recognize the contribution of wheel and rail irregularities to impact load.

Figure 3 compares Eurocode and ACI 358 impact factors, assuming a constant frequency of 3.0 Hz. As shown, the ACI-358 yields an impact factor greater than either of the Eurocode equations.

The Concessionaire continued to support its findings by referencing a survey of North American Transit Agencies conducted by AREMA. The survey showed that 10 of the 13 agencies responding use different impact provisions than the AREMA equations. The reasoning stated that AREMA impact percentages are viewed as unrealistically high for transit loading. Likewise, while the Chicago Transit Authority and the San Diego Metropolitan Transit Development Board use AREMA equations, each also agrees that the equations are unrealistically high for transit. Most respondents use a flat 30% impact factor or AASHTO impact factors.

The flat 30% lower limit equals the lower limit for jointed rail in the ACI-358 equations. The AREMA survey also notably stated that none of the respondents account for rail type (CWR vs. jointed) in their impact equations. Thus, more conservative impact factors are generally used to allow for the high impact generated by uneven rail joints.

**Project Rolling Stock Analysis**

Eagle Project design criteria also required additional analysis or justification of impact factors used on bridges with frequencies below 2.5 Hz for simple spans and 3.0 Hz for any one span in a series of three or more spans. This requirement by RTD is to check for a potentially resonant interaction between vehicle load frequency and structure natural frequency. If resonance occurs, a spike in vertical displacement would occur because of the dynamic load. Dynamic load displacement is a measure of impact factor. Hence, the project rolling stock analysis presented yet another opportunity to investigate the validity of ACI-358, this time using finite element analysis.
Conclusions

Consideration of AREMA guidelines, Eurocode, common industry practice, and their own Rolling Stock Analysis led the Concessionaire to conclude the impact factor equations in ACI-358 are appropriate for use in design of the Eagle Project's direct fixation bridges.

In evaluation of this decision, RTD, in its oversight role, strived to assure contract compliance. DTP was tasked with determining the dynamic impact factor to be used on Eagle Project direct fixation bridges. RTD reviewed their processes and results to ensure due-diligence had been paid to the complex and extremely crucial requirement.

RTD first evaluated DTP's investigation into the applicability of impact factor contributors to the Eagle Project direct fixation bridges. RTD agreed the use of continuous welded rail and the absence of special track work and turnouts on project DF bridges showed reduced cause for impact load. Second, DTP provided assurance that the maintenance requirements on the system would mitigate risk of wheel and rail wear. While dependence on good maintenance for proper impact load calculation presents a risk, this is a risk RTD determined it could tolerate given DTP's expertise and inherent stake in the project's performance.

RTD next considered the technical analysis, including the Rolling Stock Analysis used to validate ACI-358, which was brought under careful scrutiny. RTD provided comments and entered into numerous resolution discussions with DTP. However, the resounding conclusion remained that ACI-358 was appropriate to use in determining the impact factors for design.

Finally, RTD consulted a second former member of the ACI-358 committee; independent of the first consulted by DTP. The committee member reviewed the system and also agreed that ACI-358 is appropriate for determining impact factor on the Eagle Project direct fixation bridges.

Thorough review and numerous comment resolution meetings resulted in RTD concurrence that DTP had satisfactorily met all contract requirements and performed ample investigation in concluding that ACI-358 should be used to calculate the impact factors for design of Eagle Project direction fixation structures.

Cost Savings and Consequences

The resulting benefits of the extensive analysis and design were realized by both the Concessionaire and RTD. The Eagle Project experienced significant cost and schedule savings, much of which cannot be quantified. The cost savings is comprised partially of direct savings realized in bridge materials. However, design and construction flexibility is likely the more valuable advantage gained by the impact factor design innovation.

Direct project benefit related to the bridge construction can be estimated by identifying the advantages made possible through use of a lesser dynamic impact factor in determining bridge loads. Examples of this include reduced girder sizes and the ability to span longer distances. An increase in span lengths results in fewer spans, fewer foundations, and ultimately a significant reduction in materials and construction activity. For the over 17,000 linear feet of bridge structure on the Eagle Project, this meant an estimated savings over $2,000,000.
Likewise, this increased-span-length capability greatly increases flexibility in bridge geometry. This advantage triggers a domino-effect of cost and schedule savings. It enabled the design team to navigate the complicated urban environment encountered on the Eagle Project with significantly greater ease. Specifically, reduced foundation quantities and longer spans resulted in less utility relocation, avoidance of environmental hazards, and fewer road closures. Additionally, the reduced structure depth translates to a reduction in earth work required at abutments. Simple advantages like reduced structure depth or increased span length compounded into valuable reduction in modification to existing infrastructure and overall construction activity.

The analysis and design responsible for this savings was a direct result of innovative contract execution by RTD. As stated, RTD identified the potential for economization present in a refined approach to dynamic impact factor on its direct fixation structures. By placing the ownership on and incentivizing the performance of its concessionaire, RTD encouraged this specific design innovation and shared the cost and schedule savings with DTP.

**Summary**

The necessity for progression and growth in America’s infrastructure is a challenge undertaken by increasingly cash-strapped public agencies across the United States. As financial obstacles grow, the implementation of innovative project delivery methods will become even more imperative. Public-private-partnerships present public agencies the opportunity to reduce public cost while delivering quality projects to their constituents. This is accomplished through expanded funding resources, effective risk allocation, and encouraging innovative design and construction practices.

P3 project delivery gives public agencies the opportunity to hire a team of experts to take an ownership role in the projects improving their communities. This ownership role, including its financial stake, empowers the concessionaire and its experts to develop a high quality, yet economic system. Through identifying and specifying sources of innovation in conjunction with the concessionaire, the public agency is able to leverage expertise while avoiding incurring additional risk. This results in maximized cost savings to the public agency.

Proper execution of the P3 contract requires proper risk allocation and assignment of responsibility. The public agency should retain only the duties it can execute more efficiently than the concessionaire; including verification that contract requirements and industry standards are met. Otherwise, the concessionaire must be allowed to exercise its capabilities in project design and execution. By withdrawing from the project management and engaging in project oversight, the public agency allows for the efficient arrival at an end goal of delivering a safe, economic and high-quality project to the public.

The Eagle Project is effectively delivering commuter rail transit to the Denver region because of its innovative P3 contract. RTD leveraged its Concessionaire, DTP, by identifying specific design aspects and encouraging innovative solutions. Through comprehensive analysis, the DTP engineers identified and incorporated cost savings measures into design. Thus, overall capital costs to both DTP and RTD have been reduced. Moving forward, there is continued incentive for innovation by DTP and, therefore, continued potential for further cost savings to RTD.
REFERENCES


3 ACI 358.1R-92 – Analysis and Design of Reinforced and Prestressed-Concrete Guideway Structures, Reported by ACI Committee 358.


AUTHOR BIOGRAPHIES

Rik Lor, P.E.
Regional Transportation District
(August 2014)

Rik Lor is the Deputy Project Manager (Design) for the RTD FasTracks Eagle P3 Project. He joined RTD in September 2008. His area of expertise includes design and integration management, quality assurance and quality control, and construction oversight for transit projects. Rik has managed final design of the RTD Gold Line, Northwest Rail Line, and East Rail Line. He has previous freight and transit rail project experience in Chicago. Rik is a native of Colorado and received his B.S.C.E. from the University of Wisconsin at Madison and M.S.C.E. from the University of Illinois at Chicago and is a certified Professional Engineer.

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(August 2014)

Scott Henning is a structural engineer for Jacobs Engineering and a member of the project oversight team for the RTD FasTracks Program. He joined Jacobs in September 2010 and joined FasTracks in October 2012. Scott specializes in the analysis and design of bridge structural systems, particularly ordinary reinforced and prestressed concrete. Scott manages oversight of the bridge structures on the RTD Gold Line, Northwest Rail Line, and East Rail Line. His previous rail experience includes freight railroad bridge inspection and rehabilitation in West Virginia and Indiana. Scott received his B.S.C.E. from Texas A&M University and M.S.C.E. from the University of Illinois at Urbana-Champaign and is a certified Professional Engineer.
Budgetary Challenges

- Due to recession:
  - Cut services
  - Raise fares
  - Put off routine maintenance
- 85% of agencies reported flat/decreased capital funding (2011 APTA)
- Innovative procurement options?
  - RTD FasTracks
- Cost savings from P3

RTD FasTracks

- 2004 voter-approved
- 122 miles (CRT & LRT)
  - 6 new rail corridors
  - 3 existing LRT
- DUS transit facility
- 18 miles BRT
- 57 new transit stations
- 21,000 parking spaces

Eagle P3 Project Overview

- East Rail Line, 23 miles from DUS to DIA
- Gold Line, 11 miles from DUS to Wheat Ridge
- Northwest Rail Line, first 6 miles to Westminster
- Commuter Rail Maintenance Facility
- 2010-DBFOM awarded to DTP (34 yrs)
- “best value” $305M below original RTD estimated budget
- RTD estimate $2.5B
- DTP bid $2.2B

Eagle P3 Project Contract

- First full P3 in the country for transit
- DTP: deliver transit system
  - including rolling stock (54 vehicles)
  - O&M 28 yrs.
- Availability ratio concession (2016)
  - Payments are dependent on O&M standards
  - Up to 20% monthly payments withheld

Public-Private-Partnership

- Single entity (Concessionaire) to design, build, finance, operate & maintain (DBFOM) over an extended term
- Savings similar from D-B-B to D-B, through risk transfer
- Risk management
  - Whoever can manage each risk the best should take that risk on!
  - Public entity: performance standards
  - Private entity: detailed design specifications
  - Caution: Public entity does not take back risks by micro-managing Concessionaire’s responsibilities!
Risk Allocation

<table>
<thead>
<tr>
<th>RTD Risk</th>
<th>Concessionaire Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROW Attainment – Delays gaining access to the construction sites</td>
<td>Design Standards and Design Innovation</td>
</tr>
<tr>
<td>RTD requested changes to project requirements</td>
<td>Design and construction non-conformances and delays</td>
</tr>
<tr>
<td>RID Request</td>
<td>Final Completion Requirements</td>
</tr>
<tr>
<td>Ridership and fare evasion risk</td>
<td>Failure to meet operating performance standards</td>
</tr>
<tr>
<td>RTD Services Interface</td>
<td>Operations and Maintenance Costs</td>
</tr>
<tr>
<td>Timeliness of third party design reviews</td>
<td>Condition of system at end of concession period</td>
</tr>
</tbody>
</table>

Concessionaire Design Risk

- RTD tasked DTP with developing an Eagle Project Design Basis Manual
  - Provided RTD CRT Design Criteria as a basis
  - Compared final products to improve RTD Design Criteria for future work
  - Specific Task: Determine dynamic impact factor for design of DF CRT bridges

RTD Assurance

- DTP Financial Stake
  - $240M or roughly 10.9%
- Performance requirement/incentive
  - Guaranteed project completion date
  - Availability Ratio
  - DTP Risk of Default
- Maintenance Responsibility

Design Innovation

“For bridges on which tracks are directly affixed, the Concessionaire shall perform analyses or justifications to determine design parameters including live load distribution factor, impact factor, and forces due to temperature variations in the rail, addressing both unbroken and broken rail conditions”

Concession Agreement Attachment 7 Part B 5.5(e)

RTD Motivations

- Leverage Concessionaire’s expertise and motivation to determine a safe, yet economic impact factor
  - AREMA Impact = 200% (conservative for CRT)
- Retained ability to review Concessionaire’s analysis
  - In concert with Rolling Stock Analysis (RSA)

Concessionaire Methodology

- ACI-358.1R-92
  “Analysis and Design of Prestressed- and Reinforced Concrete Guideway Structures”
  - 10% minimum for Continuous Welding Rail

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Concessionaire Methodology

• Supporting Data
  – Eurocode
  – Survey of other U.S. Transit Systems
• Rolling Stock Analysis (RSA)
  – Eagle Project requirement to investigate potential for resonance effects
  – Results supported ACI-358 Impact values

RTD Evaluation

• Applicability of ACI-358
• Were all factors considered?
• Technical Review
  – Acceptable for design
    – DTP used dynamic impact factors in the range of 10% for DF bridges

Contract Compliance

“For bridges on which tracks are directly affixed, the Concessionaire shall perform analyses or justifications to determine design parameters including live load distribution factor, impact factor, and forces due to temperature variations in the rail, addressing both unbroken and broken rail conditions”

Concession Agreement Attachment 7 Part B 5.5(e)

Resulting Gains

• Material Savings
  – Estimated Savings of $2,000,000
• Construction Schedule
• Design Flexibility
  – Most valuable advantage gained

Summary

• Transit Agencies are cash-strapped
  – Look into more creative procurement methods
  – RTD (P3)
• Public entity risk management
  – Performance standards vs design specifications
  – Focus on safety, user experience & reliability
  – Allow Concessionaire freedom to innovate!
• End Goal: deliver a safe, high-quality and economic project to the public

Questions