CT
Innovations

TT-W004

Mitigating Critical Path Risks:

TOUGHTray

TOUGH
SUPPORT SAVINGS

1.0 ABSRACT

This paper investigates the intricate correlation between the utilization of structural steel in cable tray systems and the associated project schedule critical path risks and budget costs. Through comprehensive analysis and case studies, we examine the impact of steel support structure on the cable tray project schedule, providing insight for effective risk mitigation strategies.

This paper starts by establishing the correlation between:
a. *Project Schedule Constraints and Cable Tray Schedule Critical Path Risks.*
b. *Cable Tray Critical Path Schedule Risks* and *TSS Schedule Risk Mitigation Solutions.*

This paper presents a series of *'Manufacturer Design Recommendations'* that have been developed and implemented. The papers final section contains a demonstration of the schedule risks and solution advantages available, when applied to a typical energy project with approximated structural material savings of <u>$7M</u> and <u>34,000</u> engineering and erection hours.

2.0 INTRODUCTION

National energy security and environmental concerns are driving the energy transition, while societies adoption of new data technology is driving increased demand for products and services. These combined needs are driving increased demand for new electrical infrastructure that the construction industry must deliver against a backdrop of market constraints such as the availability and cost of materials and skilled labor.

Innovation is required to alleviate and overcome those market challenges. Industry must deliver solutions that can be easily and efficiently implemented using minimal resources with quantified cost and risk mitigation strategies.

This paper focuses on structural design solutions that deliver efficient cable tray design using minimal resources throughout the project cycle to reduce construction schedule risks and budget costs. It is important that early consideration be given to cable tray design practices and solutions that mitigate critical path risk and budgeted cost. It is recommended this be during project front end engineering design.

3.0 CABLE TRAY CPM SCHEDULING

The critical path method (CPM) is a common technique used for scheduling in construction. The critical path in a construction project refers to the sequence of activities that determine the project's overall duration. These activities are interconnected by dependencies, meaning a delay in one activity can impact the project's timeline.

By identifying the critical path, a project manager can prioritize activities, allocate resources effectively, and ensure that the project remains on track to meet the completion date. It will help a project manager to identify potential risks and to mitigate them accordingly.

The cable tray system is generally considered a critical path item within the construction schedule. Any delay to the cable tray systems design, supply and installation will delay the following dependent construction activities, such as wiring installation, E&I equipment termination and ultimately the E&I systems commissioning.

4.0 SCHEDULE CONSTRAINTS AND SCHEDULE RISKS CORRELATION

Considering the listed *Project Schedule Constraints* and correlation to *Cable Tray Schedule Critical Path Risks*.

Schedule Constraints			Schedule Critical Path Risks
a.	Tray Design Flexibility	CORRELATION	Budget Increase & Schedule Delay: inefficient and inflexible design solutions increase structural design complexity, engineering schedule and structural material costs.
b.	Tray Design Resources		Budget Increase & Schedule Delay: availability can delay the completion of cable tray structural support design, fabrication, erection, and scheduled tray installation.
c.	Raw Material Costs		Budget Increase & Schedule Delay: availability constraints and the fluctuating cost of raw materials can increase structural steel material costs, budget and schedule.
c.	Tray Civil Structural		Budget Increase & Schedule Delay: cable tray steel support structure can result in high civil structural content, increasing civil structural material costs, budget and schedule.
d.	Tray Installation		Budget Increase & Schedule Delay: stagnant tray designs can be inefficient to use, they increase installation complexity, time and resources, construction costs and schedule.

5.0 SCHEDULE RISKS AND TSS SCHEDULE RISK SOLUTIONS CORRELATION

Considering the listed *Schedule Critical Path Risks* and correlation to *TSS Schedule Risk Mitigation Solutions*.

Schedule Constraints			Schedule Risks		TSS Schedule Risk Mitigation Solutions
a.	Tray Design Flexibility	CORRELATION	Budget Increase & Schedule Delay	CORRELATION	TSS provides greater design flexibility for location of cable tray structural steel supports and/or their elimination entirely. Flexibility to efficiently optimize cable tray support structure. Mitigating structural design constraints and schedule risks.
b.	Tray Design Resources		Budget Increase & Schedule Delay		TSS reduces the quantity and design complexity of cable tray structural steel supports. Designing less structure requires less skilled resource time to complete the structural support design. Mitigating skilled resource constraints and schedule risks.
c.	Materials & Logistics		Budget Increase & Schedule Delay		TSS reduces the quantity of cable tray structural steel support, structural steel material costs, their logistic and handling costs. Mitigating material costs, logistic costs and schedule risks.
c.	Tray Civil Structural		Budget Increase & Schedule Delay		TSS reduces the quantity of cable tray structural steel support, structural material costs and associated civil structure works. Mitigating structural costs, civil costs and schedule risks.
d.	Tray Installation		Budget Increase & Schedule Delay		TSS reduces quantity of cable tray structural steel supports by 50 to 100%. Installing less structure to minimize site works. Mitigating cable tray installation time, cost and schedule risks.

If a projects budget for purchasing cable tray is $10M, by applying TSS design solutions the attainable cost saving is indicatively $10M by reducing the cable tray structural support material and associated construction costs. The quantified cost advantage of the TSS risk mitigation solutions presented by this paper is compelling. The project management team is encouraged to evaluate and quantify these solutions at the earliest possible project stage.

6.0 DESIGN PHILOSOPHIES

The tray system design objective is simply to produce a compliant tray design that safely supports and protects the electrical systems wiring cables. Engineered in accordance with industry standards and design techniques that ensure compliance with national regulations, a typical tray system engineering output can be:

- *Tray Size*
- *Tray Design Load*
- *Tray Support Span*
- *Tray Routing Layouts & 3D Models*
- *Construction Detailing*
- *Material Take Offs*

In many instances this engineering objective will be completed with little consideration to the cable tray systems structural support system. An example could be optimizing cable tray widths to meet calculated cable fill volumes. Although this will minimize the tray size it will create a need to add a reducing fitting, which requires a dedicated structural support. This may result in a significant increase to a cable tray systems structural material content, the associated structural engineering and steel erection costs. Structural material content, costs and schedule risks that once factored in, may result in higher project costs and greater schedule risks than intended or planned for.

When considering the cable tray system is a structural support system that not only interfaces with the electrical wiring system but also the civil structural; engineering the cable tray system to minimize steel structure and any associated civil structural construction would provide the greatest project cost advantage and mitigation of the project schedule critical path risks.

Industry Standards: NEMA VE 1, NEMA VE 2, IEC 61537, ASCE/SEI 7
National Regulations: NFPA-70 (National Electrical Code)

7.0 INDUSTRY STANDARD DESIGN PRACTICES

When determining the required location of structural steel supports for the cable tray system, the engineering will generally refer to industry standard NEMA VE 2 recommendations. It should be noted that the NEMA VE 2 recommendations are just that, recommendations and not must dos; it simply provides design guidance.

How can we apply the recommendations of NEMA VE 2 wisely? And can applying the guidance in blind obedience be detrimental to a cable tray systems structural design and critical path?

Let us start by considering what the recommendations are, and how they apply to the cable tray systems structural support system.

7.1 Cable Tray Supports

NEMA publication VE 2 Section 3.3.1 quote "*supports for cable trays should provide strength and working load capabilities sufficient to meet the load requirement of the cable tray wiring system. Consideration should be given to loads associated with future cable additions or any other additional loads applied to the cable tray system or the cable tray support system*" unquote.

It is evident from this quote, that structural support design must consider multiple factors to adequately support the cable ladder tray system. Generally, the supports structural engineering must consider:

a. Cable tray weights
   - *Straight sections (lbs/ft)*
   - *Straight section covers (lbs/ft)*
   - *Fittings (lbs)*
   - *Fitting Covers (lbs)*

b. Cable weight
   - *Cable design load (lbs/ft)*

c. Future cable additions should refer to:
   - *NEC Article 392 for allowable cable fill*
   - *NEMA VE 1 for allowable cable tray loads*

d. Other additional loads applied to the cable tray system can be:
   - *Dynamic wind load*
   - *Dynamic seismic load*
   - *Static snow load*
   - *Static ice load*

Section 7.1 relates to the structural design of the cable tray support itself which is not the focus of this paper. This section is provided only to highlight the inherent structural design complexities, engineering resources and time required to complete this project schedule task.

7.2 Recommended Support Locations for Fittings

Cable tray fittings are:

- *Horizontal Elbow, Tee, Cross, Wye, Reducer*
- *Vertical Elbow, Tee*

For each fitting type the recommended location of structural support is given by:

- *NEMA Standards Publication VE 2 Cable Tray Installation Guidelines*
- *Section 3.5.1 Recommended Support Locations for Fittings.*

Quote "*Recommended support locations follow, unless otherwise recommended by manufacturer*" unquote. This therefore, provides the design engineer with two options for the location of fitting supports:

- *to follow NEMA VE 2 recommendations and figures.*
- *to follow the cable tray manufacturer recommendations and figures "TSS Design Solutions".*

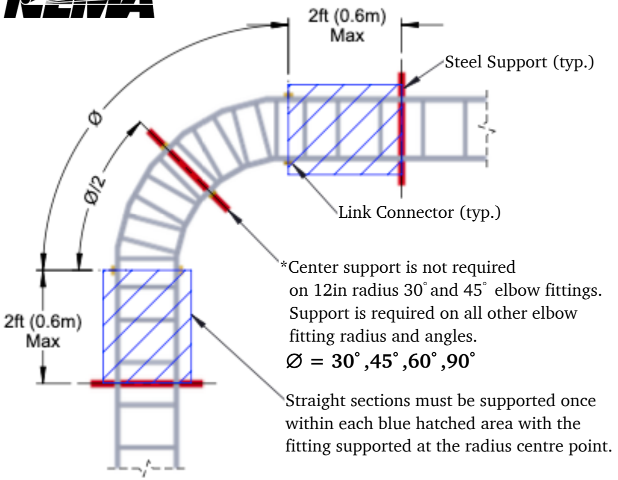
The following fitting support recommendations are considered:

7.2a. *Horizontal Elbow Support: (VE 2 Figure 3.54) | (TSS Figure 3.1B)*
7.2b. *Horizontal Tee Support: (VE 2 Figure 3.55) | (TSS Figure 3.2B)*
7.2c. *Horizontal Cross Support: (VE 2 Figure 3.57) | (TSS Figure 3.3B)*
7.2d. *Vertical Cable Tray Elbows: (VE 2 Figure 3.39) | (TSS Figure 4.1C)*

Each support recommendation will be analyzed for:

- *Structure Design Flexibility*
- *Support Structure Quantity*
- *Schedule Critical Path Risk*

7.2a Horizontal Elbow Support (VE 2 : 3.5.1.1)



*Center support is not required on 12in radius 30˚ and 45˚ elbow fittings. Support is required on all other elbow fitting radius and angles.

Ø = 30˚,45˚,60˚,90˚

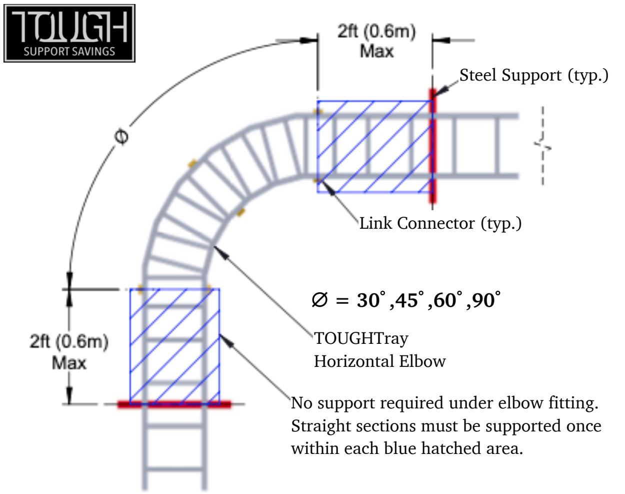
Straight sections must be supported once within each blue hatched area with the fitting supported at the radius centre point.

VE 2 Figure 3-54

Industry Standard Practice : Support Locations

VE 2	Design Flexibility	Material Quantity	Critical Path Risk
	10%	3	100%

7.2a Horizontal Elbow Support (TSS : Figure 3.1B)



Ø = 30˚,45˚,60˚,90˚

TOUGHTray
Horizontal Elbow

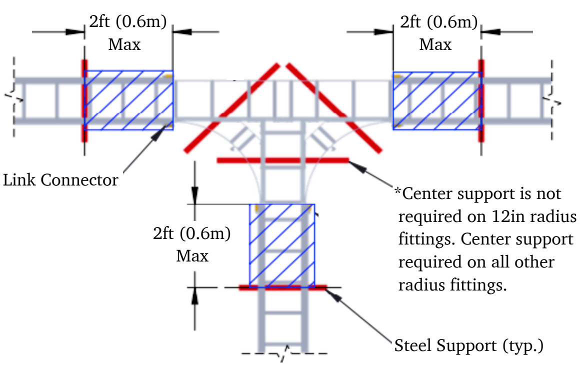
No support required under elbow fitting. Straight sections must be supported once within each blue hatched area.

TSS Figure 3.1B

Manufacturer Recommended: Support Locations

	Design Flexibility	Material Quantity	Critical Path Risk
	33%	3	67%

7.2b Horizontal Tee Support (VE 2 : 3.5.1.2)



*Center support is not required on 12in radius fittings. Center support required on all other radius fittings.

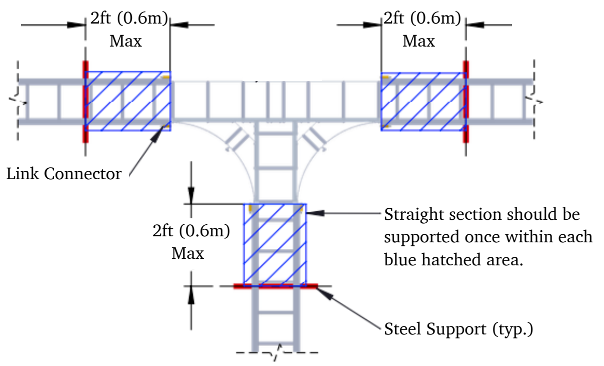
Steel Support (typ.)

VE 2 Figure 3-55

Industry Standard Practice : Support Locations

VE 2	Design Flexibility	Material Quantity	Critical Path Risk
	5%	6	100%

7.2b Horizontal Tee Support (TSS : Figure 3.2B)



Straight section should be supported once within each blue hatched area.

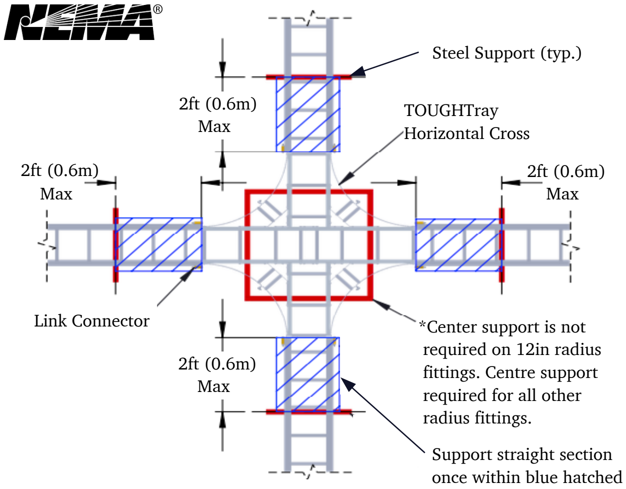
Steel Support (typ.)

TSS Figure 3.2

Manufacturer Recommended: Support Locations

	Design Flexibility	Material Quantity	Critical Path Risk
	40%	3	50%

7.2c Horizontal Cross Support (VE 2 : 3.5.1.4)



*Center support is not required on 12in radius fittings. Centre support required for all other radius fittings.

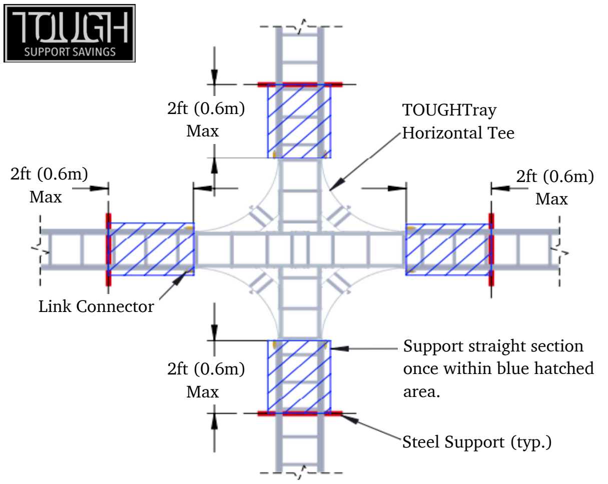
Support straight section once within blue hatched area.

VE 2 Figure 3-55

Industry Standard Practice : Support Locations

VE 2	Design Flexibility	Material Quantity	Critical Path Risk
	5%	8	100%

7.2c Horizontal Cross Support (TSS : Figure 3.3B)



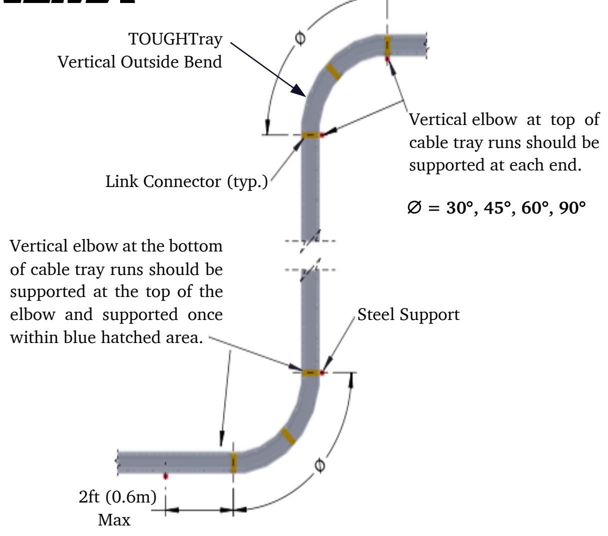
Support straight section once within blue hatched area.

TSS Figure 3.3B

Manufacturer Recommended: Support Locations

	Design Flexibility	Material Quantity	Critical Path Risk
	50%	4	50%

7.2d Vertical Elbow Support (VE 2 : 3.5.1.6)



Vertical elbow at top of cable tray runs should be supported at each end.

Ø = 30°, 45°, 60°, 90°

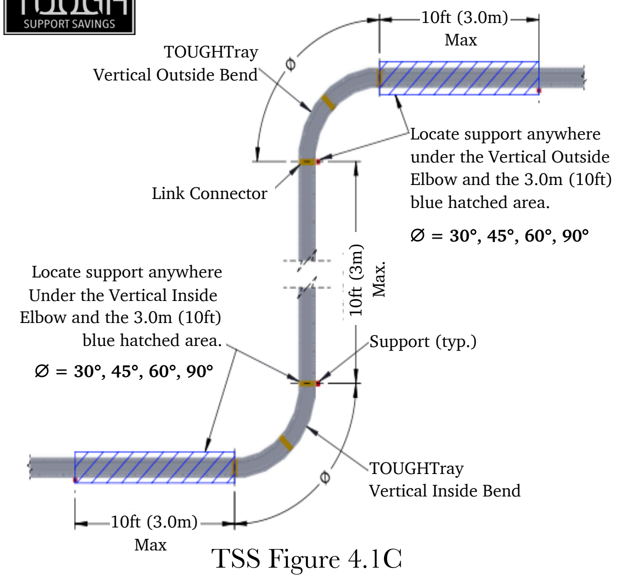
Vertical elbow at the bottom of cable tray runs should be supported at the top of the elbow and supported once within blue hatched area.

VE 2 Figure 3-59

Industry Standard Practice : Support Locations

VE 2	Design Flexibility	Material Quantity	Critical Path Risk
	5%	4	100%

7.2d Vertical Elbow Support (TSS : Figure 4.1C)



Locate support anywhere under the Vertical Outside Elbow and the 3.0m (10ft) blue hatched area.

Ø = 30°, 45°, 60°, 90°

Locate support anywhere Under the Vertical Inside Elbow and the 3.0m (10ft) blue hatched area.

Ø = 30°, 45°, 60°, 90°

TSS Figure 4.1C

Manufacturer Recommended: Support Locations

	Design Flexibility	Material Quantity	Critical Path Risk
	80%	2	20%

7.3 Expansion Joints

Cable tray continuous straight runs will thermally expand and contract under thermal dynamic loads.

Expansion joints are required to manage the thermal expansion/contraction, located and structurally supported in accordance with Industry Standard NEMA VE 2, Section 3.4.2.

Quote *"Supports should be located within 600 mm (2 ft) of each side of the expansion splice plates. Expansion splice joints should be designed and placed so as to maximize the rigidity of the cable tray, unless expansion splice plates are part of a system specifically designed for other placement, including over supports or mid-span"* unquote.

This recommendation raises questions concerning thermal expansion design. Clarifying these questions is important to ensure:

- *maximum rigidity of the cable tray*
- *minimum structural supports*

Questions:

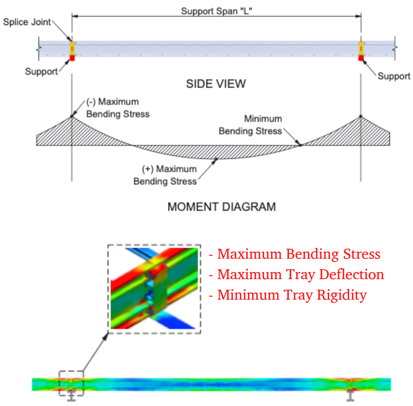
A. *how do you design and place the expansion joint to maximize the rigidity of the cable tray?*
B. *what are the thermal performance implications?*
C. *what are the structural support implications?*
D. *what are the construction schedule risks?*

Clarifications:

Let us consider the following expansion joint locations to analyze and answer questions A., B., C., D.

- *over support expansion joint location (7.3.1)*
- *mid-span expansion joint location (7.3.2)*
- *quarter-span expansion joint location (7.3.3)*

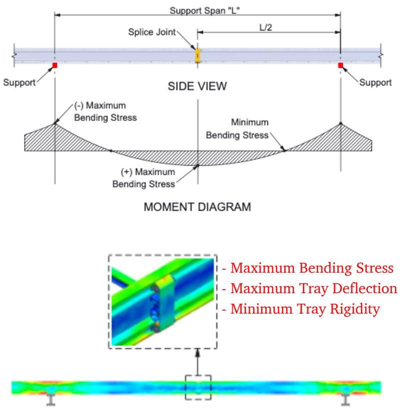
7.3.1 Over Support Location



- Maximum Bending Stress
- Maximum Tray Deflection
- Minimum Tray Rigidity

A. Rigidity:	Max. Bending Stress
B. Thermal:	Poor Performance
C. Structure:	No Additional Supports
D. Schedule:	High Critical Path Risk
Location is Not Recommended	

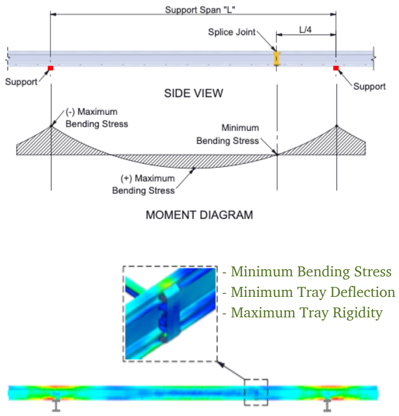
7.3.2 Mid-Span Location



- Maximum Bending Stress
- Maximum Tray Deflection
- Minimum Tray Rigidity

A. Rigidity:	High Bending Stress
B. Thermal:	Poor Performance
C. Structure:	2 Additional Supports
D. Schedule:	High Critical Path Risk
Location is Not Recommended	

7.3.3 Quarter-Span Location



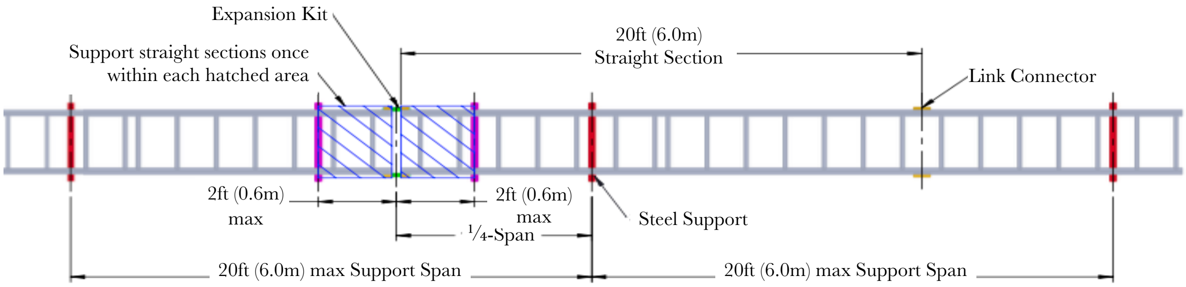
- Minimum Bending Stress
- Minimum Tray Deflection
- Maximum Tray Rigidity

A. Rigidity:	No Bending Stress
B. Thermal:	Good Performance
C. Structure:	No Additional Supports
D. Schedule:	No Critical Path Risk
Location is Recommended	

7.3.3 Recommended Quarter-Span Location

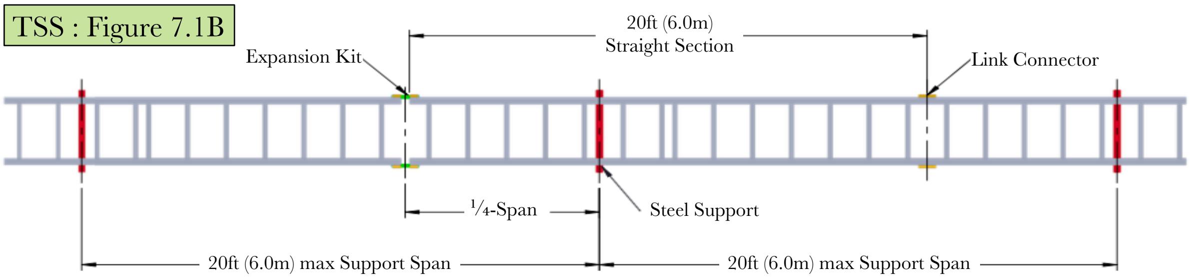
When the located at the recommended quarter-span a standard expansion splice plate may require additional structural support as shown below Figure 3-39. To eliminate additional structural support a self-supporting expansion cartridge kit is recommended, as shown in below TSS : Figure 7.1B.

VE 2 : Figure 3-39



Industry Standrad Practice Structurally Supported Joint	VE 2	Design Flexibility	Material Quantity	Critical Path Risk
		0%	2	100%

TSS : Figure 7.1B



Manufacturer Recommended Self Supported Joint		Design Flexibility	Material Quantity	Critical Path Risk
		100%	0	0%

8.0 SOLUTIONS SUMMARY

This table provides summary of the solutions contained within Section 7.0. This shows if the solution mitigates the Section 4.0 constraints and risks. Green indicates a high mitigation of risk, and Red indicates no risk mitigation.

Section #	Figure #	Section 4.0 Schedule Constraint & Risk Solution Summary									
		Design Flexibility		Design Resources		Material Handling		Structural Steel		Installation	
7.2a	3-54		0%		100%		100%		100%		100%
7.2a	3.1B	33%		67%		67%		67%		67%	
7.2b	3-55		0%		100%		100%		100%		100%
7.2b	3.2B	50%		50%		50%		50%		50%	
7.2c	3-57		0%		100%		100%		100%		100%
7.2c	3.3B	50%		50%		50%		50%		50%	
7.2d	3-59		0%		100%		100%		100%		100%
7.2d	4.1C	80%		50%		50%		50%		50%	
7.3	3-39		0%		100%		100%		100%		100%
7.3	7.1B	100%		0%		0%		0%		0%	

9.0 WORKED PROJECT EXAMPLE

Finally, we consider a projects cable tray system. Based on the below material take-off, we analyze the cable tray structural support system requirements when following NEMA VE-2 Recommendations and TSS Manufacturer Recommendations. The analysis and comparisons consider and quantify the following:

a. *Quantity of structural cable tray supports required.*
b. *Weight of structural cable tray supports required.*
c. *Time to engineer the structural supports.*
d. *Time to erect the structural supports.*
e. *Cost of the support structure.*

9.1 CABLE TRAY SYSTEM MATERIAL TAKE-OFF

Item #	Quantity	UoM	Cable Tray Part #	NEMA VE 1	Cable Tray Description
1.0	12200	1-Piece	TTS09-6X12X20C-AL	20 C	6H 12W 240L 20C ST SC
1.1	9800	1-Piece	TTS09-6X24X20C-AL	20 C	6H 24W 240L 20C ST SC
1.2	14100	1-Piece	TTS09-6X36X20C-AL	20 C	6H 36W 240L 20C ST SC
2.0	400	1-Piece	TTF-6X12-90HB24-AL	20 C	6H 12W 90D 24R HB
2.1	130	1-Piece	TTF-6X12-90HB36-AL	20 C	6H 12W 90D 36R HB
2.2	980	1-Piece	TTF-6X24-90HB24-AL	20 C	6H 24W 90D 24R HB
2.3	80	1-Piece	TTF-6X24-90HB36-AL	20 C	6H 24W 90D 36R HB
2.4	1320	1-Piece	TTF-6X36-90HB24-AL	20 C	6H 36W 90D 24R HB
2.5	170	1-Piece	TTF-6X36-90HB36-AL	20 C	6H 36W 90D 36R HB
3.0	480	1-Piece	TTF-6X12X12-HT24-AL	20 C	6H 12W 24R HT
3.1	75	1-Piece	TTF-6X12X12-HT36-AL	20 C	6H 12W 36R HT
3.2	160	1-Piece	TTF-6X24X24-HT24-AL	20 C	6H 24W 24R HT
3.3	40	1-Piece	TTF-6X24X24-HT36-AL	20 C	6H 24W 36R HT
3.4	690	1-Piece	TTF-6X36X36-HT24-AL	20 C	6H 36W 24R HT
3.5	85	1-Piece	TTF-6X36X36-HT36-AL	20 C	6H 36W 36R HT
4.0	18	1-Piece	TTF-6X12X12-HX24-AL	20 C	6H 12W 24R HX
4.1	5	1-Piece	TTF-6X12X12-HX36-AL	20 C	6H 12W 36R HX
4.2	9	1-Piece	TTF-6X24X24-HX24-AL	20 C	6H 24W 24R HX
4.3	2	1-Piece	TTF-6X24X24-HX36-AL	20 C	6H 24W 36R HX
4.4	23	1-Piece	TTF-6X36X36-HX24-AL	20 C	6H 36W 24R HX
4.5	12	1-Piece	TTF-6X36X36-HX36-AL	20 C	6H 36W 36R HX
5.0	820	1-Piece	TTF-6X12-90VI24-AL	20 C	6H 12W 90D 24R VI
5.1	20	1-Piece	TTF-6X12-90VI36-AL	20 C	6H 12W 90D 36R VI
5.2	840	1-Piece	TTF-6X12-90VO24-AL	20 C	6H 12W 90D 24R VO
5.3	15	1-Piece	TTF-6X12-90VO36-AL	20 C	6H 12W 90D 36R VO
5.4	455	1-Piece	TTF-6X24-90VI24-AL	20 C	6H 24W 90D 24R VI
5.5	60	1-Piece	TTF-6X24-90VI36-AL	20 C	6H 24W 90D 36R VI
5.6	510	1-Piece	TTF-6X24-90VO24-AL	20 C	6H 24W 90D 24R VO
5.7	45	1-Piece	TTF-6X24-90VO36-AL	20 C	6H 24W 90D 36R VO
5.8	840	1-Piece	TTF-6X36-90VI24-AL	20 C	6H 36W 90D 24R VI
5.9	70	1-Piece	TTF-6X36-90VI36-AL	20 C	6H 36W 90D 36R VI
5.10	850	1-Piece	TTF-6X36-90VO24-AL	20 C	6H 36W 90D 24R VO
5.11	55	1-Piece	TTF-6X36-90VO36-AL	20 C	6H 36W 90D 36R VO
6.0	2033	1-Pair	TTA-EXPNKIT-6	20 C	6H 12W EXPANSION
6.1	1633	1-Pair	TTA-EXPNKIT-6	20 C	6H 24W EXPANSION
6.2	2350	1-Pair	TTA-EXPNKIT-6	20 C	6H 36W EXPANSION

9.2 NEMA VE-2 INDUSTRY STANDARD RECOMMENDATIONS vs. TSS MANUFACTURER RECOMMENDATIONS

Item	Tray Description	UoM	Qty	Structural Tray Supports Qty		Structure Weight (Ton)		Design Time (Hrs)		Erection Time (Hrs)		Structure Cost ($M)	
				NEMA	TSS	NEMA	TSS	NEMA	TSS	NEMA	TSS	NEMA	TSS
1.1	6"H 12"W 20C ST SC	1-Pc	12200	12200	12200	226.9	226.9	3,025	3,025	12,100	12,100	2.745	2.745
1.2	6"H 24"W 20C ST SC	1-Pc	9800	9800	9800	306.3	306.3	2,450	2,450	9,800	9,800	3.706	3.706
1.3	6"H 36"W 20C ST SC	1-Pc	14100	14100	14100	616.9	616.9	3,525	3,525	14,100	14,100	7.464	7.464
2.1	6H 12W 90D 24R HB	1-Pc	400	1200	800	28.1	15.6	720	360	1,440	1,440	0.340	0.189
2.2	6H 12W 90D 36R HB	1-Pc	130	390	260	9.3	5.1	195	98	390	390	0.112	0.061
2.3	6H 24W 90D 24R HB	1-Pc	980	2940	1960	76.4	44.6	1,470	735	2,940	2,940	0.925	0.540
2.4	6H 24W 90D 36R HB	1-Pc	80	240	160	7.3	4.2	120	60	240	240	0.088	0.050
2.5	6H 36W 90D 24R HB	1-Pc	1320	3960	2640	128.7	77.2	1,980	990	3,960	3,960	1.557	0.934
2.6	6H 36W 90D 36R HB	1-Pc	170	510	340	18.8	11.1	255	128	510	510	0.227	0.134
3.1	6H 12W 24R HT	1-Pc	480	1920	1440	39.0	21.8	1,200	720	1,920	1,920	0.472	0.264
3.2	6H 12W 36R HT	1-Pc	75	300	225	7.1	3.9	188	113	300	300	0.086	0.047
3.3	6H 24W 24R HT	1-Pc	160	640	480	17.2	10.4	400	240	640	640	0.208	0.126
3.4	6H 24W 36R HT	1-Pc	40	160	120	4.8	2.9	100	60	160	160	0.058	0.035
3.5	6H 36W 24R HT	1-Pc	690	2760	2070	91.9	58.3	1725	1,035	2,760	2,760	1.113	0.705
3.6	6H 36W 36R HT	1-Pc	85	340	255	12.4	7.7	213	128	340	340	0.150	0.094
4.1	6H 12W 24R HX	1-Pc	18	90	72	2.2	1.3	54	36	90	90	0.026	0.016
4.2	6H 12W 36R HX	1-Pc	5	25	20	0.7	0.4	15	10	25	25	0.009	0.005
4.3	6H 24W 24R HX	1-Pc	9	45	36	1.4	0.9	27	18	45	45	0.017	0.011
4.4	6H 24W 36R HX	1-Pc	2	10	8	0.4	0.2	6	4	10	10	0.004	0.003
4.5	6H 36W 24R HX	1-Pc	23	115	92	4.5	2.8	69	46	115	115	0.054	0.034
4.6	6H 36W 36R HX	1-Pc	12	60	48	2.7	1.6	36	24	60	60	0.032	0.020
5.1	6H 12W 90D 24R VI	1-Pc	820	1640	820	37.3	8.0	1,230	410	1,640	1,640	0.317	0.068
5.2	6H 12W 90D 36R VI	1-Pc	20	40	20	1.2	0.2	30	10	40	40	0.010	0.002
5.3	6H 12W 90D 24R VO	1-Pc	840	1680	840	38.2	8.2	683	420	1,680	1,680	0.325	0.069
5.4	6H 12W 90D 36R VO	1-Pc	15	30	15	0.9	0.1	90	8	30	30	0.007	0.001
5.5	6H 24W 90D 24R VI	1-Pc	455	910	455	26.6	7.4	1,260	228	910	910	0.226	0.063
5.6	6H 24W 90D 36R VI	1-Pc	60	120	60	4.3	1.0	105	30	120	120	0.036	0.008
5.7	6H 24W 90D 24R VO	1-Pc	510	1020	510	29.8	8.3	1,260	255	1,020	1,020	0.254	0.070
5.8	6H 24W 90D 36R VO	1-Pc	45	90	45	3.2	0.7	23	23	90	90	0.027	0.006
5.9	6H 36W 90D 24R VI	1-Pc	840	1680	840	60.1	19.1	765	420	1,680	1,680	0.511	0.162
5.10	6H 36W 90D 36R VI	1-Pc	70	140	70	5.8	1.6	68	35	140	140	0.050	0.014
5.11	6H 36W 90D 24R VO	1-Pc	850	1700	850	60.8	19.3	1,275	425	1,700	1,700	0.517	0.164
5.12	6H 36W 90D 36R VO	1-Pc	55	110	55	4.6	1.3	83	28	110	110	0.039	0.011
6.1	6H 12W EXPANSION	1-Pr	2017	4034	0	65.5	0.0	3050	0	4,034	0	0.793	0.000
6.2	6H 24W EXPANSION	1-Pr	1633	3268	0	74.3	0.0	2450	0	3,268	0	0.899	0.000
6.3	6H 36W EXPANSION	1-Pr	2350	4700	0	137.5	0.0	3525	0	4,700	0	1.663	0.000
		TOTALS:		72,967	51,706	2,153.1	1,495.3	33,670	16,097	73,107	61,105	25.068	17.821
		TSS SAVINGS:			29.1%		30.6%		52.2%		16.4%		28.9%

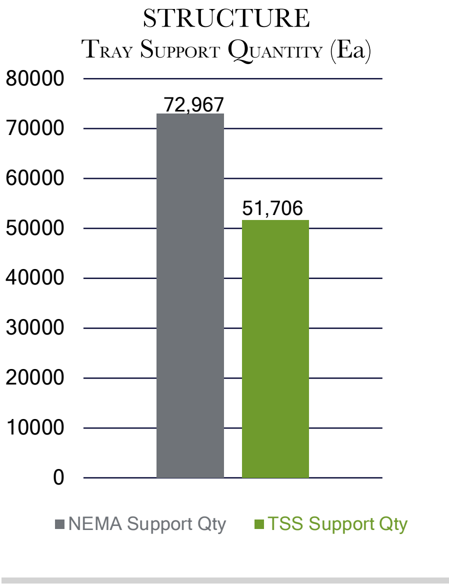
Reference Data:

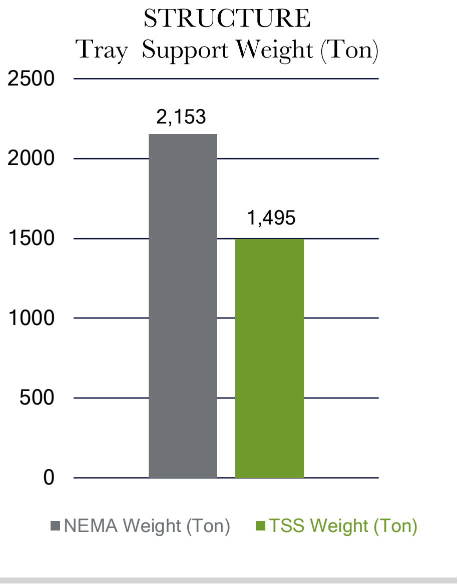
- Structural support steel sections are:
  - *straight sections: S10 x 25 beam | 25 lb/ft weight.*
  - *fittings & expansion joints: C6 x 13 channel | 13 lb/ft weight.*

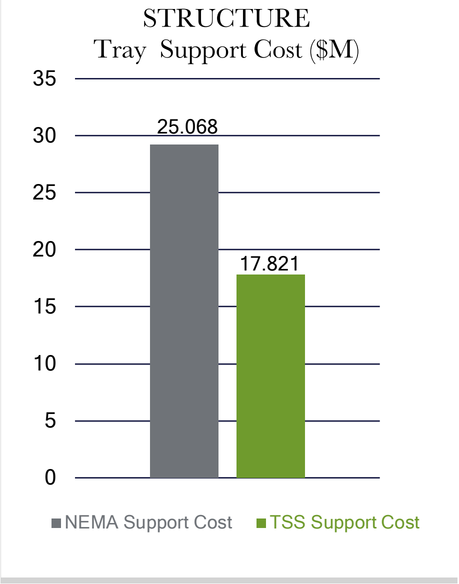
- Structural support cost is a sum of:
  - *material: $1.5/Lb*
  - *fabrication: $2.0/Lb*
  - *handling: $0.25/Lb.*
  - *erection: $2.0/Lb.*

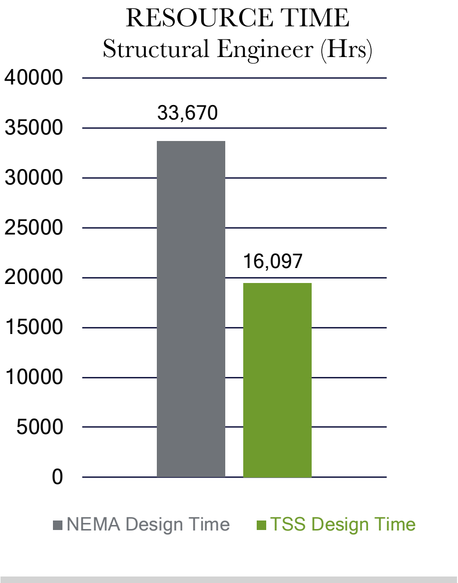
10.0 TABULATION OF DESIGN RECOMMENDATIONS

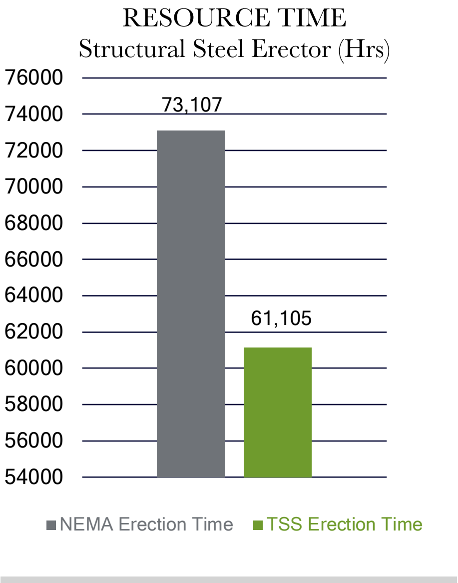
Considering the data provided by Table 9.2, the below tabulated data shows significant % reductions in structural materials, skilled resources and costs. The reductions directly mitigate the identified risks to a project schedules cable tray critical path.











11.0 SUMMARY OF RISK AND COST MITIGATION

With consideration to the data presented, we can summarize the risks and cost mitigation benefits as follows:

11.1 NEMA VE 2 industry standard practice design recommendations.

a. 00.00% reduction in structural supports quantity
b. 00.00% reduction in engineering resource time
c. 00.00% reduction in structural erection time
d. 00.00% reduction in structural materials weight
e. 00.00% reduction in structural materials cost

Standard practices are restrictive and do not reduce cable tray support structure materials or costs.

11.2 TSS manufacturer design recommendations.

a. 29.17% reduction in structural supports quantity 21,291 pcs. saved
b. 25.06% reduction in engineering resource time 22,697 hrs. saved
c. 16.42% reduction in structural erection time 12,002 hrs. saved
d. 23.69% reduction structural material weight 1.315M lbs. saved
e. 23.94% reduction structural material cost $7.247M saved

TSS practices provide greater design flexibility and reduce cable tray support structure materials and costs.

11.3 TSS recommendations demonstrate mitigation of the following risks to the cable tray critical path.

a. Reduces structural engineering design & erection hours : *mitigates resource constraints*
b. Reduces quantity of tray support structure : *mitigates structural material and site erection costs*
c. Reduces weight of structural materials : *mitigates logistic and handling costs*

TSS design recommendations provide greater critical path risk mitigation compared to industry standard practices.

12.0 CONCLUSIONS

Industry standard practices although fit for purpose, do present challenges and risks that can be mitigated by the selection and implementation of alternate manufacturer solutions and recommendations.

Based on the findings of this paper:

a. Cable tray selection should consider the impact of the tray structural supports and the associated schedule and budget risks at the earliest possible stage of a project. This is recommended to be during project FEED.

b. Selecting a cable tray system designed to reduce structure will save resources, materials, time and money while mitigating budget constraints and critical path risks. This is recommended to be during project FEED.

13.0 REFERENCES & TOOLS

To aid in the evaluation of cable ladder tray installation efficiency, the following technical papers and quantification tools are available to the reader and recommended by the author. https://www.toughinnovations.com/resources

a. TOUGH Support Savings Calculator
b. TT-W005: Structural Design Efficiency
c. TT-W006: Improving Installation Efficiency

Mark Vincent Bowman
Chief Specification Officer
CT INNOVATIONS