Brief Engineering Assessment: Efficiencies available through simultaneous construction and co-location of communications conduit and fiber

Prepared for the National Association of Telecommunications Officers and Advisors and the City and County of San Francisco
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Table of Contents

Table of Figures

Table of Tables

1. Introduction and Summary of Conclusions

The following is a brief engineering assessment of the efficiencies available through simultaneous construction and co-location of communications conduit and fiber.

The construction of fiber optic communications cables is a costly, complex, and time consuming process. The high cost of construction is a barrier to entry for potential broadband communications providers. Available space is diminishing in the public rights of way. Cutting roads and sidewalks substantially reduces the lifetime and performance of those surfaces.

In summary, encouraging or requiring simultaneous construction and co-location of facilities in the public right of way will reduce the long-term cost of building communications facilities. This is because there are significant economies of scale through:

1. Coordination of construction with road construction and other disruptive activities in the public right of way.
2. Construction of spare conduit capacity where multiple service providers or entities may require infrastructure.

The reason that these economies are available is primarily because *fiber optic cables and installation materials alone are relatively inexpensive, often contributing to less than one quarter of the total cost of new construction.* While material costs typically fall well below $40,000 per mile (even for large cables containing hundreds of fiber strands), labor, permitting, and engineering costs commonly drive the total price towards $200,000 per mile (Table 1).

Moreover, as the ROW becomes more crowded with communications infrastructure and other utilities, the cost of new construction can grow exponentially. There are, of course, always exceptions – the benefits of collaboration tend to diminish in more rural settings. In general, however, it is in the best interests of commercial and public entities to identify construction collaboration opportunities that share the burden of expensive and duplicative labor-related costs and efficiently utilize physical space in the ROW.

If fiber construction is coordinated with a major road or utility project that is already disrupting the right of way, the incremental cost of constructing the fiber, communications conduit, and other materials ranges from $70,000 per mile to $135,000 for a single conduit. However, if fiber construction is completed as part of a separate standalone project, the cost of constructing fiber and communications conduit can range from $95,000 to $200,000 per mile.

Savings through coordination with the road or utility project can therefore range from 25% to 33%, and is greatest in crowded areas where the complexity and cost of construction is highest.

Construction of utilities or roads can provide further savings if multiple communications entities coordinate their construction and pursue a "joint trench" opportunity. In that case, multiple providers share the cost of the trenching and the design. If there are three providers in the joint trench, the cost *per entity* ranges from $55,000 to $92,000 per mile, resulting in a savings of 40% to 50% relative to construction that is not coordinated with road construction or other communications entities.

This brief report provides 1) general background on fiber optic construction and the advantages of coordination and 2) case studies explaining and detailing construction cost estimates.

2. Background

2.1 Advantage of Underground Construction

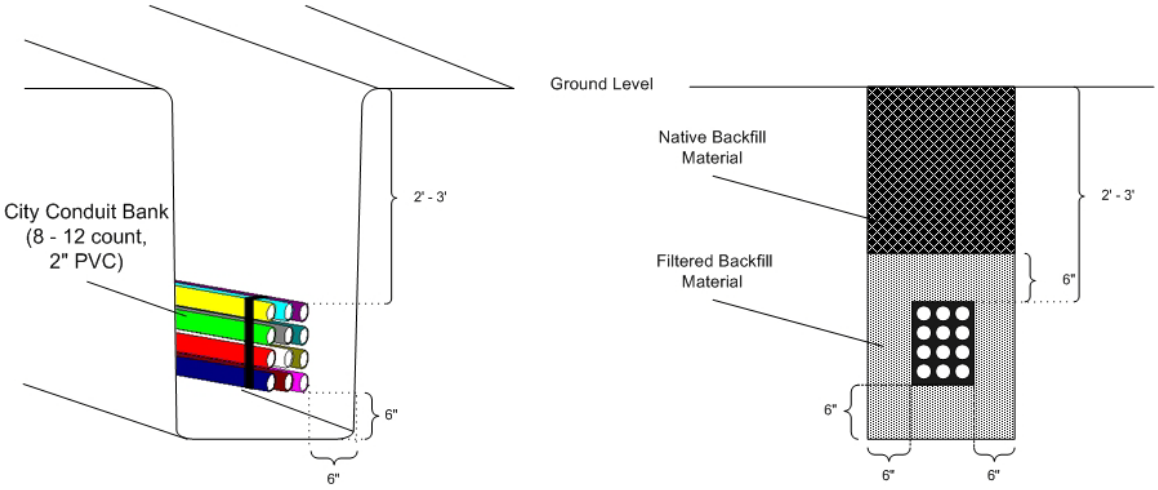
There are numerous methods for constructing fiber optic infrastructure. In particular, underground construction using protective conduits generally provides the most scalable, flexible, and durable method for developing long-term communications infrastructure, but is also typically more expensive than aerial construction methods requiring attachments to utility poles. This is because of the limit in the quantity of cables and attachments that can be placed on existing utility poles in more crowded areas, and because aerial construction is more exposed and vulnerable to outside conditions.

2.2 Advantage of Coordinated, Simultaneous Construction

Banks of conduits constructed *simultaneously* (Figure 1), or large conduits segmented with inner duct, provide multiple pathways for the installation of multiple fiber optic cables located in close proximity, with the scalability to remove, add, or replace fiber optic cables without disturbing neighboring cables.

Conversely, multiple conduits installed at different times must be physically spaced, often by several feet, to prevent damage to one while installing the next. Once the ROW becomes crowded, often the choices of construction methods are reduced, leaving only less desirable methods and more costly locations for construction of additional infrastructure.

Figure 1: Underground Conduit Bank for Multiple Users



Some of the key cost components that can be avoided or reduced through coordinated construction efforts include:

- Overall reduction in incremental labor and material costs through reduced crew mobilization expenses and through larger bulk material purchases;
- Trenching or boring costs, particularly when coordination enables lower cost methods (trenching as opposed to boring) or allows multiple entities to share a common trench or bore for their independent purposes;
- Traffic control and safety personnel, particularly when constructing along roadways requiring lane closures;
- Engineering and survey costs associated with locating existing utilities and specifying the placement location of new facilities;
- Engineering and survey costs associated with environmental impact studies and approvals;
- Lease fees for access to private easements, such as those owned by electric utilities;
- Railroad crossing permit fees and engineering;
- Restoration to the ROW or roadway, particularly in conjunction with roadway improvements; and
- Bridge crossing permit fees and engineering.

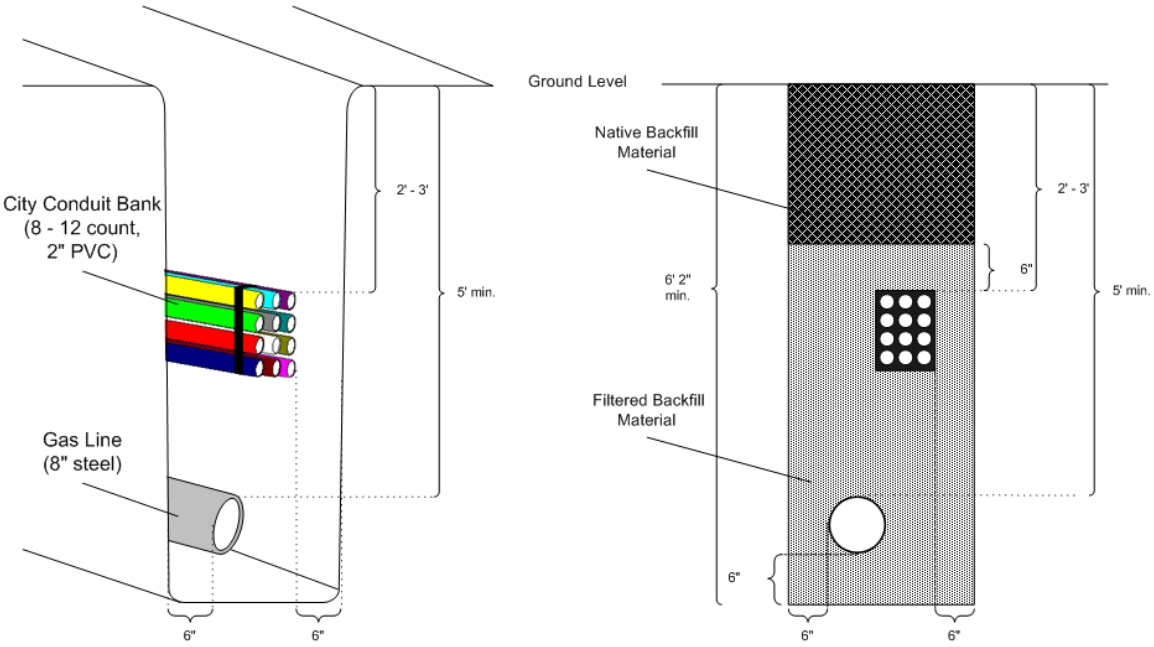
2.3 Advantage of Coordination with Other Utility Projects

Where other types of construction are occurring within or along the ROW, such as roadway widening, sidewalk repairs, bridge construction, and water or gas main installation, there is an opportunity to acquire telecommunications infrastructure at an

overall reduced cost and with reduced disruption to public ROW.

Figure 2 illustrates how a multi-user conduit bank might be installed with a gas main, water main, power line, or other large utility installation requiring trenching. We note that in a case like this, it is important to ensure proper backfill of trench material and facilitate future access to both the conduit and the other utility for repair by offsetting the two utilities horizontally and requiring a somewhat wider trench. This offsets somewhat the potential cost savings by requiring a larger trench and multistep backfill process. Nonetheless, cost savings are still substantial.

Figure 2: Example Coordinated Conduit Bank and Gas Main Installation



3. Construction Case Studies with Different Degrees of Coordination

We offer the following construction scenarios reflecting real-world per-mile estimates to compare costs for incremental construction with and without collaborative opportunities in varying construction environments. For each scenario, we present a range of costs encompassing variation in labor rates and variations in the complexity of construction, from rural areas to relatively developed areas:

1. Construction of Single 2" Conduit Independent of Road Construction Project
2. Construction of Single 2" Conduit Coordinated with Road Construction Project
3. Construction of Three Separate Uncoordinated 2" Conduit Independent of Road Construction Project
4. Construction of Three Separate 2" Conduit Coordinated with Road Construction Project (Joint Trench)

3.1 Scenario 1 – Construction of Single 2" Conduit Independent of Road Construction

This example is bound by the following basic characteristics:

- 216-strand count;
- The segment is part of a backbone or a "middle mile" backbone run, as opposed to a last-mile Fiber to the Premises (FTTP) deployment targeting each home or business passed;
- Roadway crossings and a railroad crossing are required;
- Underground vaults are placed at intervals of 500-feet in areas requiring typical restoration; and
- All construction is new, using underground directional boring.

We estimate per-mile construction costs to range from approximately $95,000 to over $195,000 per mile (Table 1), or more if significant ROW space issues occur.

Table 1: Scenario 1 – Construction of Single 2" Conduit Independent of Road Construction

Independent 2" Conduit Run for Single User

LABOR

Category	Quantity	Unit	Low Cost/Unit	High Cost/Unit	Low Cost	High Cost
Design	5,280	FT.	$0.08	$0.10	$422	$528
Engineering and Permits	5,280	FT.	$0.25	$0.25	$1,320	$1,320
Railroad Crossing	1	LOT	$5,000.00	$15,000.00	$5,000	$15,000
Directional Boring for 2" Conduit	5,280	FT.	$8.00	$20.00	$42,240	$105,600
Directional Boring for 4" Conduit	0	FT.	$11.00	$25.00	$0	$0
Trenching for 24" - 36" Depth	0	FT.	$5.00	$12.00	$0	$0
Place Conduit	5,280	FT.	$1.00	$1.75	$5,280	$9,240
Place Inner Duct	0	FT.	$0.50	$1.50	$0	$0
Place Vault	11	EACH	$500.00	$750.00	$5,500	$8,250
Place Fiber in Conduit	5,280	FT.	$1.25	$2.50	$6,600	$13,200
Install Splice Enclosure	1	EACH	$300.00	$500.00	$300	$500
Splice Fiber	216	EACH	$12.00	$30.00	$2,592	$6,480
TOTAL LABOR					**$69,254**	**$160,118**

MATERIALS

Category	Quantity	Unit	Low Cost/Unit	High Cost/Unit	Low Cost	High Cost
216 Count Fiber	6,072	FT.	$1.80	$2.50	$10,930	$15,180
Splice Kit	1	EACH	$500.00	$750.00	$500	$750
4" Conduit and Materials	0	FT.	$2.98	$3.50	$0	$0
2" Conduit and Materials	5,280	FT.	$0.88	$1.50	$4,646	$7,920
1" Inner Duct	0	FT.	$0.30	$0.45	$0	$0
Vault	11	EACH	$450.00	$600.00	$4,950	$6,600
Tax and Freight	1	LOT	$2,102.60	$3,045.00	$2,103	$3,045
TOTAL MATERIAL					**$23,129**	**$33,495**

3.2 Scenario 2 – Single 2" Conduit Coordinated with Road Construction

We compare typical per-mile construction costs for constructing underground telecommunications fiber in conduit in conjunction with the installation of a road construction project. Similar savings can also result from coordination with a new utility line, such as a natural gas main or water supply main (Figure 2). We assume fiber infrastructure costs are incremental to the full costs of independent construction of the utility. This example is bound by the following basic characteristics:

- A telecommunications provider requires fiber optic cable construction over the same basic physical routing to support large fiber cables of a nominal 216-strand count;
- The segment is part of a backbone or a "middle mile" backbone run, as opposed to a last-mile Fiber to the Premises (FTTP) deployment targeting each home or business passed;
- Roadway crossings and a railroad crossing are required;

- Underground vaults are placed at intervals of 500-feet in areas requiring typical restoration; and
- All construction is new using underground trenching.

We estimate per-mile construction costs to range from approximately $70,000 per mile to over $135,000 per mile (Table 2), or more if significant ROW space issues occur.

Table 2: Scenario 2 -- Construction of Single 2" Conduit Coordinated with Road Construction Project

Independent 2" Conduit Run for Single User Co-Location

LABOR

Category	Quantity	Unit	Low Cost/Unit	High Cost/Unit	Low Cost	High Cost
Design	5,280	FT.	$0.08	$0.10	$422	$528
Engineering and Permits	0	FT.	$0.25	$0.25	$0	$0
Railroad Crossing	0	LOT	$5,000.00	$15,000.00	$0	$0
Directional Boring for 2" Conduit	0	FT.	$8.00	$20.00	$0	$0
Directional Boring for 4" Conduit	0	FT.	$11.00	$25.00	$0	$0
Trenching for 24" - 36" Depth	5,280	FT.	$5.00	$12.00	$26,400	$63,360
Place Conduit	5,280	FT.	$1.00	$1.75	$5,280	$9,240
Place Inner Duct	0	FT.	$0.50	$1.50	$0	$0
Place Vault	11	EACH	$500.00	$750.00	$5,500	$8,250
Place Fiber in Conduit	5,280	FT.	$1.25	$2.50	$6,600	$13,200
Install Splice Enclosure	1	EACH	$300.00	$500.00	$300	$500
Splice Fiber	216	EACH	$12.00	$30.00	$2,592	$6,480
TOTAL LABOR					**$47,094**	**$101,558**

MATERIALS

Category	Quantity	Unit	Low Cost/Unit	High Cost/Unit	Low Cost	High Cost
216 Count Fiber	5,280	FT.	$1.80	$2.50	$9,504	$13,200
Splice Kit	1	EACH	$500.00	$750.00	$500	$750
4" Conduit and Materials	0	FT.	$2.98	$3.50	$0	$0
2" Conduit and Materials	5,280	FT.	$0.88	$1.50	$4,646	$7,920
1" Inner Duct	0	FT.	$0.30	$45.00	$0	$0
Vault	11	EACH	$450.00	$600.00	$4,950	$6,600
Tax and Freight	1	LOT	$1,960.04	$2,847.00	$1,960	$2,847
TOTAL MATERIAL					**$21,560**	**$31,317**

3.3 Scenario 3 – Three, Separate, Uncoordinated 2" Conduit Independent of Road Construction Project

We compare typical per-mile construction costs for constructing underground telecommunications fiber in three separate conduit, not coordinated with each other or with any road or utility construction projects. The cost is approximately three times the cost of Scenario One, although costs can increase even further if the first construction projects have appreciably reduced the available ROW.

This example is bound by the following basic characteristics:

- Each telecommunications provider requires fiber optic cable construction over the same basic physical routing to support large fiber cables of a nominal 216-strand count;
- The segment is part of a backbone or a "middle mile" backbone run, as opposed to a last-mile Fiber to the Premises (FTTP) deployment targeting each home or business passed;
- Roadway crossings and a railroad crossing are required;
- Underground vaults are placed at intervals of 500-feet in areas requiring typical restoration; and
    - All construction is new, using directional boring.

We estimate per-mile construction costs to range from approximately $280,000 per mile to over $580,000 per mile (Table 3), or more if significant ROW space issues occur (Table 3).

Table 3: Scenario 3 -- Construction of Three Separate Uncoordinated 2" Conduit Independent of Road Construction Project

Independent 2" Conduit Run for Three Users

LABOR

Category	Quantity	Unit	Low Cost/Unit	High Cost/Unit	Low Cost	High Cost
Design	15,840	FT.	$0.08	$0.10	$1,267	$1,584
Engineering and Permits	15,840	FT.	$0.25	$0.25	$3,960	$3,960
Railroad Crossing	3	LOT	$5,000.00	$15,000.00	$15,000	$45,000
Directional Boring for 2" Conduit	15,840	FT.	$8.00	$20.00	$126,720	$316,800
Directional Boring for 4" Conduit	0	FT.	$11.00	$25.00	$0	$0
Trenching for 24" - 36" Depth	0	FT.	$5.00	$12.00	$0	$0
Place Conduit	15,840	FT.	$1.00	$1.75	$15,840	$27,720
Place Inner Duct	0	FT.	$0.50	$1.50	$0	$0
Place Vault	33	EACH	$500.00	$750.00	$16,500	$24,750
Place Fiber in Conduit	15,840	FT.	$1.25	$2.50	$19,800	$39,600
Install Splice Enclosure	3	EACH	$300.00	$500.00	$900	$1,500
Splice Fiber	648	EACH	$12.00	$30.00	$7,776	$19,440
TOTAL LABOR					**$207,763**	**$480,354**
MATERIALS						
Category	**Quantity**	**Unit**	**Low Cost/Unit**	**High Cost/Unit**	**Low Cost**	**High Cost**
216 Count Fiber	18,216	FT.	$1.80	$2.50	$32,789	$45,540
Splice Kit	3	EACH	$500.00	$750.00	$1,500	$2,250
4" Conduit and Materials	0	FT.	$2.98	$3.50	$0	$0
2" Conduit and Materials	15,840	FT.	$0.88	$1.50	$13,939	$23,760
1" Inner Duct	0	FT.	$0.30	$0.45	$0	$0
Vault	33	EACH	$450.00	$600.00	$14,850	$19,800
Tax and Freight	1	LOT	$6,307.80	$9,135.00	$6,308	$9,135
TOTAL MATERIAL					**$69,386**	**$100,485**

3.4 Scenario 4 – Three Separate 2" Conduit Coordinated with Road Construction Project (Joint Trench)

We compare typical per-mile construction costs for constructing underground telecommunications fiber in three separate conduit, coordinated with a road or utility construction project in a joint trench.

This example is bound by the following basic characteristics:

- Each telecommunications provider requires fiber optic cable construction over the same basic physical routing to support large fiber cables of a nominal 216-strand count;
- The segments are part of a backbone or a "middle mile" backbone run, as opposed to a last-mile Fiber to the Premises (FTTP) deployment targeting each home or business passed;

- Roadway crossings and a railroad crossing are required;
- Underground vaults are placed at intervals of 500-feet in areas requiring typical restoration; and
- All construction is new, using underground trenching.

We estimate per-mile construction costs to range from approximately $160,000 per mile to over $280,000 per mile (Table 3), or more if significant ROW space issues occur.

The per mile costs of any of the above scenarios can be compared with the incremental cost attributed to each owner of the communications infrastructure, illustrating the most significant cost savings compared to other construction coordination opportunities. We estimate per-mile construction costs to be approximately $55,000 per entity (or conduit), or a total of over $95,000 per mile (Table 4), leveraging open trench. In this scenario, per mile costs would be the approximately same per entity regardless of the number of collaborative partners (or conduits) over a fairly wide range, since a large trench is necessary for the utility installation providing the coordination opportunity.

Table 4: Scenario 4 -- Construction of Three Separate 2” Conduit Coordinated with Road Construction Project (Joint Trench)

Independent 2" Conduit Run for Three User Co-Location

LABOR

Category	Quantity	Unit	Low Cost/Unit	High Cost/Unit	Low Cost	High Cost
Design	5,280	FT.	$0.08	$0.10	$422	$528
Engineering and Permits	0	FT.	$0.25	$0.25	$0	$0
Railroad Crossing	0	LOT	$5,000.00	$15,000.00	$0	$0
Directional Boring for 2" Conduit	0	FT.	$8.00	$20.00	$0	$0
Directional Boring for 4" Conduit	0	FT.	$11.00	$25.00	$0	$0
Trenching for 24" - 36" Depth	5,280	FT.	$5.00	$12.00	$26,400	$63,360
Place Conduit	15,840	FT.	$1.00	$1.75	$15,840	$27,720
Place Inner Duct	0	FT.	$0.50	$1.50	$0	$0
Place Vault	33	EACH	$500.00	$750.00	$16,500	$24,750
Place Fiber in Conduit	15,840	FT.	$1.25	$2.50	$19,800	$39,600
Install Splice Enclosure	3	EACH	$300.00	$500.00	$900	$1,500
Splice Fiber	648	EACH	$12.00	$30.00	$7,776	$19,440
TOTAL LABOR					**$87,638**	**$176,898**

MATERIALS

Category	Quantity	Unit	Low Cost/Unit	High Cost/Unit	Low Cost	High Cost
216 Count Fiber	18,216	FT.	$1.80	$2.50	$32,789	$45,540
Splice Kit	3	EACH	$500.00	$750.00	$1,500	$2,250
4" Conduit and Materials	0	FT.	$2.98	$3.50	$0	$0
2" Conduit and Materials	15,840	FT.	$0.88	$1.50	$13,939	$23,760
1" Inner Duct	0	FT.	$0.30	$45.00	$0	$0
Vault	33	EACH	$450.00	$600.00	$14,850	$19,800
Tax and Freight	1	LOT	$6,307.80	$9,135.00	$6,308	$9,135
TOTAL MATERIAL					**$69,386**	**$100,485**

Of course, a nearly infinite number of possible scenarios and cost models can be presented, but in most cases, clear construction cost savings can be realized on the whole through collaborative efforts in the right of way. These scenarios do not consider non-engineering matters, such as conduit ownership, license agreements, and the impact that low-cost, competitive access to conduit might have on the business cases for constructing fiber, whether positive or negative, for different entities.