The Potential for Ubiquitous, Open Fiber-to-the-Premises in San Francisco

FIBER FOR SAN FRANCISCO INITIATIVE

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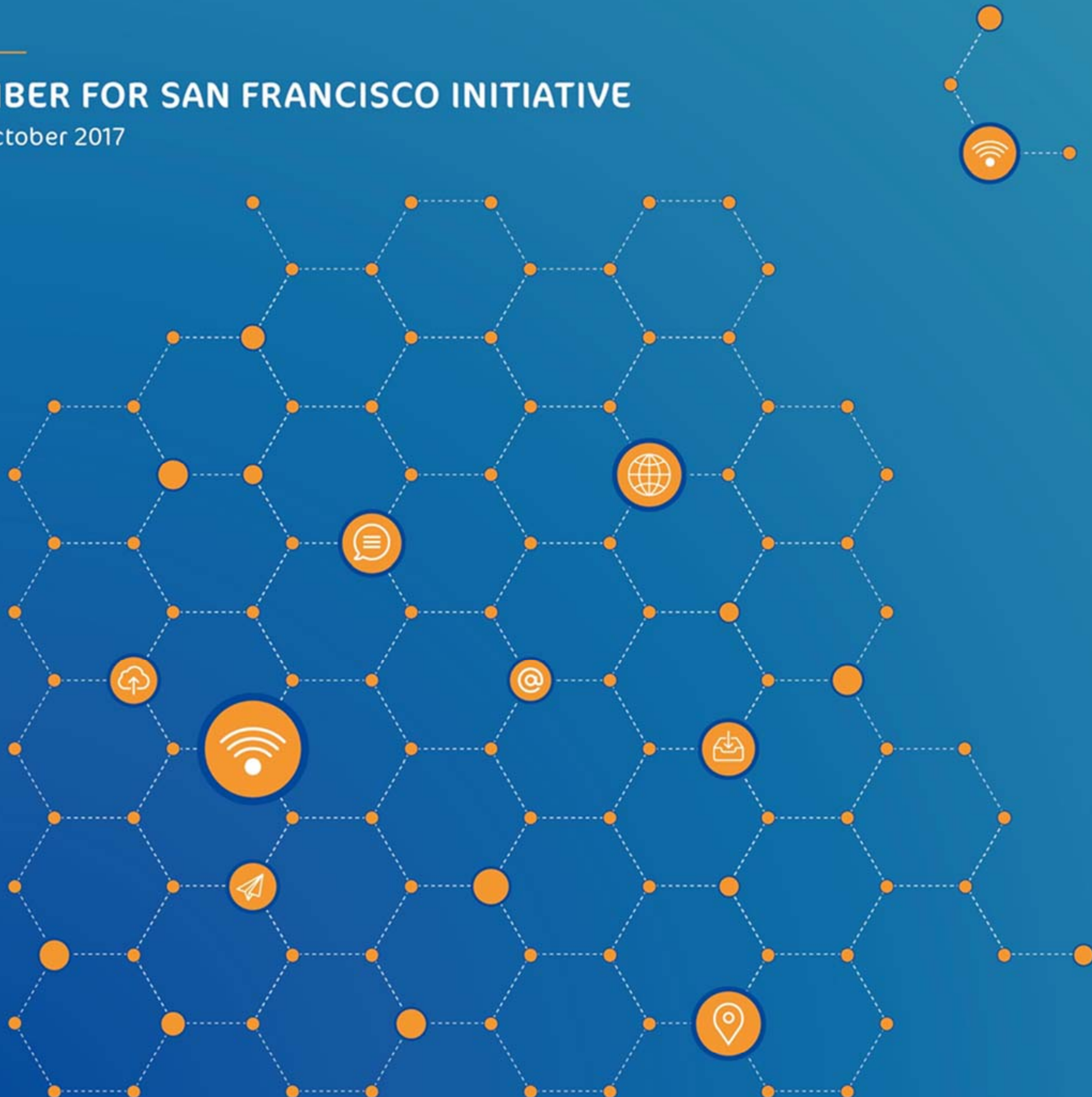

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Contents

Figures

Tables

1 Executive Summary

Broadband networks rank among the most important infrastructure assets of our time—for purposes of economic development and competitiveness, innovation, workforce preparedness, healthcare, education, democratic discourse, and environmental sustainability. The City and County of San Francisco (City) recognizes the need for essential high-speed, affordable broadband services in the City and is considering how to facilitate development of such services, including to those with no or limited access or ability to afford high-quality services.

The City commissioned this report in early 2017 from a Project Team that includes CTC Technology & Energy, a public sector broadband consultancy,[1] and IMG Rebel, a financial advisory and P3 structuring firm.[2]

The City directed the Project Team to develop a delivery strategy for delivery of services over **ubiquitous fiber-to-the-premises** (FTTP, or fiber connectivity to every home and business in San Francisco) that would be **open, offering equal potential access** to the network by multiple entities so as to enable and stimulate competition. The City directed the Project Team to consider the potential for (1) fully public, (2) fully private, or (3) public–private partnership (P3) arrangements for financing, designing, constructing, maintaining, and operating the network. In addition to the ubiquity and openness parameters for the fiber, the City articulated the following key principles to guide the effort:

- **Equity:** Every resident and business in San Francisco should have access to fast and affordable broadband connectivity necessary to participate and thrive in the 21st century. With 13.2 percent of the City's residents living below the poverty level, affordability of broadband services is a significant factor in the City's digital inclusion efforts. The City intends to prioritize providing service to traditionally underserved households.

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[1] CTC Technology & Energy is a 30-year-old broadband consultancy focused on public sector and non-profit efforts to improve government and utility communications, expand broadband internet service, and develop new strategies for delivery of network capabilities, including broadband public–private partnerships and innovative collaborations. CTC offers strategy, engineering, business planning, project management, and grant planning services. CTC's clients include the cities of San Francisco, Seattle, Portland (Ore.), Washington, D.C., Boston, Atlanta, San Antonio, Vancouver, B.C., and hundreds of other cities and counties of all sizes. CTC is the leading broadband consultancy working with the application of P3 concepts to broadband in such projects as KentuckyWired and the Westminster, Maryland, fiber P3. CTC also helped define the framework for broadband P3s in the Benton Foundation's paper on "The Emerging World of Broadband Public–Private Partnerships" (https://www.benton.org/sites/default/files/partnerships.pdf).

[2] IMG Rebel is among the world's leading P3 advisors. IMG Rebel has advised on more than 50 P3 transactions across sectors as lead transaction advisor, including many first-of-its-kind deals. IMG Rebel has supported most of the leading U.S. federal, state, and local P3 practitioners, including the states of Florida, Texas, and Virginia and the Federal Highway Administration's (FHWA) Office of Innovative Project Delivery as a financial and/or P3 advisor.

- **Jobs, Innovation, Growth:** Investment in new connectivity will result in increased local employment and provide numerous economic development advantages for the entire City to continue to be the innovation capital of the world.
- **Local Authority:** A San Francisco owned fiber network will protect the City's stated values of equity, privacy, net neutrality, and open access.

To identify a sustainable approach to facilitating both the City's technical solution (ubiquitous, open access FTTP) and policy goals (with a focus on equity), the Project Team undertook the following analyses:

1. Developed a technical design and cost estimate for deployment of a fiber network that would connect every home and business in San Francisco
2. Considered three delivery models for execution of the ubiquitous, open FTTP goal: purely public, purely private, and P3
3. Developed two innovative P3 delivery strategies and financial models for financing, designing, constructing, maintaining, and operating a network that meet the City's required parameters:
    a. A Dual P3 Model in which the City would develop two P3s, one for dark fiber/outside plant only, and one to deliver lit services to every home and business, while also providing wholesale services to competing service providers
    b. A Single Dark Fiber P3 Model in which the City would develop one P3 for dark fiber, and then lease dark fiber to competing service providers who would light and operate the fiber
4. Developed a procurement strategy for the P3 that applies P3 best practices to the new asset class of broadband while seeking to appropriately improve the broadband market and leverage the potential demand (on the part of both consumers and internet service providers) for new competition opportunities

1.1 Fiber-to-the-Premises Design and Cost Estimate

CTC's engineers prepared a network design and cost estimate for an open fiber optic infrastructure to connect to all homes and businesses in San Francisco.[3] The recommended architecture is a hierarchical data network that provides critical scalability and flexibility, both in initial network deployment and in capacity to accommodate the increased demands of future applications and technologies. It includes the following characteristics:

[3] This analysis is described in detail in Section 2 below.

- Capacity – ability to provide efficient transport for subscriber data, even at peak levels
- Availability – high levels of redundancy, reliability, and resiliency; ability to quickly detect faults and re-route traffic
- Failsafe operation – physical path diversity to minimize operational impact resulting from fiber or equipment failure
- Efficiency – no traffic bottlenecks; efficient use of resources
- Scalability – ability to grow in terms of physical service area and increased data capacity, and to integrate newer technologies
- Manageability – simplified provisioning and management of subscribers and services
- Flexibility – ability to provide different levels and classes of service to different customer environments; can support an open-access network or a single-provider network; can provide separation between service providers on the physical layer (separate fibers) or logical layer (separate VLAN or VPN providing networks within the network)
- Security – controlled physical access to all equipment and facilities, plus network access control to devices

With input from City public works and engineering staff regarding both costs and City processes, the Project Team then developed cost estimates,[4] assuming City cost structures,[5] for the following:

[4] The network design and cost estimates are based on data and insight gathered by CTC engineers in discussions with City stakeholders and an extensive field and desk survey of candidate fiber routes. The design and cost estimation methodology are discussed in detail below.

[5] All of CTC's cost estimates for this report are based on our experience with municipal cost structures, rather than those of the private sector. As a result, some of these estimates will vary from the likely costs that would be incurred by a P3 concessionaire. We chose this methodology for two reasons: First, while the private sector can realize some kinds of efficiencies that public entities cannot, this is unlikely to impact the most significant of the cost areas, labor. We presume based on City guidance that any P3 awardee will be required to pay salaries and benefits in compliance with City policy, which may be higher than private market rates. We note that the P3 concessionaire may be able to improve on our cost estimates through the benefits of scale, particularly in the areas of equipment purchases, customer service, and other operating costs, but given the City's living wage commitments, significantly reduced costs for construction labor are unlikely. Second, given that this project represents a first-of-its-kind evaluation, there does not exist in the broadband field a set of data regarding private costs and bidding levels for FTTP P3s. This is unlike P3 planning in other sectors, where multiple P3s have been executed and public sponsors are able to draw on data developed in earlier projects and bids. As a result, we deliberately chose the conservative methodology of estimating based on municipal cost structures. We anticipate that P3 bidders will be able to greatly improve on our conservative estimates in the areas of equipment

- **A "lit" FTTP network**, including the costs to deploy FTTP outside plant infrastructure, as well as all electronics, consumer drops, and customer premises equipment (CPE). This estimate shows the total capital cost to build an FTTP network to support ubiquitous 1 Gbps (gigabit per second) data service
- **A "dark" FTTP network**, including the cost to deploy only the outside plant infrastructure. This is the total capital cost for the City to build a dark FTTP network for use by one or more entities

The Project Team estimates that the lit FTTP network deployment will cost $1.9 billion,[6] inclusive of outside plant construction labor, materials, engineering, permitting, pole attachment licensing, network electronics, drop installation, CPE, and testing.[7] We estimate the average construction cost per passing[8] will be $2,050.[9] The costs are summarized in Section 2.4.[10]

Table 1: Estimated Lit FTTP Cost

Cost Component	Low-Cost Scenario	High-Cost Scenario
Outside Plant	$700 million	$760 million
Central Network Electronics	112 million	112 million
FTTP Service Drop and Lateral Installations	680 million	740 million
Customer Premises Equipment	290 million	290 million
Total Estimated Cost:	$1.8 billion	$1.9 billion

We estimate that a dark FTTP network deployment will cost $1.5 billion,[11] inclusive of outside plant construction labor, materials, engineering, permitting, pole attachment licensing, and

procurement, equipment maintenance, customer service, and other costs associated with operations of the lit fiber network.

6 This is the High-Cost Scenario as described below.

7 Because the City directed that the analysis assume the network will be deployed in a "utility" model to all homes and businesses within San Francisco, the estimated total cost breakdown assumes that 100 percent of residents and businesses will be connected to the service. In a delivery model in which the network is built only to those consumers who choose to purchase service, the total cost to connect and associated network deployment costs would be lower.

8 The passing count includes individual single-unit buildings and units in multi-dwelling and multi-business buildings as single passings. In larger multi-dwelling units (MDU), the cost estimate assumes that existing wiring will be used to serve the units. We assume that each unit in large MDUs will cost $500.

9 This is the High-Cost Scenario as described below.

10 We apply an uncertainty of +/- 20 percent based on our experience and typical industry practice.

11 This is the High-Cost Scenario as described below.

lateral drop and materials. This estimate, which does not include any electronics or subscriber equipment, is summarized in Section 2.1.2.[12]

Table 2: Estimated Dark FTTP Cost

Cost Component	Low-Cost Scenario	High-Cost Scenario
Outside Plant	$700 million	$760 million
FTTP Service Drop and Lateral Installations	680 million	740 million
Total Estimated Cost	$1.4 billion	$1.5 billion

The cost estimates are based on a combination of aerial and underground construction, and a range of potential construction scenarios. The low-cost scenario assumes directional boring throughout the City using test pitting to minimize outages to existing utilities. The high-cost scenario requires high levels of surface restoration (i.e., complete sidewalk replacement).

The dark fiber estimate assumes that the City or its partner constructs and owns the FTTP infrastructure up to a demarcation point (a network interface device, or NID) at each residence and business, and that the dark fiber backbone, distribution, and drop fiber are then lit by a separate entity. The lit fiber entity would be responsible for all network electronics and customer premises equipment (CPE). The network architecture could support multiple entities using fiber assets on a leased basis or other basis.

The outside plant construction landscape in the City has changed since CTC last estimated the cost of fiber construction for San Francisco in 2009 (and even since the CostQuest study two years ago). More providers have entered the market or expanded their service footprints, which means more crowding on utility poles and higher pole make-ready costs. Further, new surface restoration standards will increase the cost of underground construction and the amount of time needed to construct the network. Utility pole replacement costs will increase, too, because taller poles will be needed in many locations to support the new fiber attachment. And existing poles continue to age—increasing the number of replacements needed.

1.2 Delivery Mechanism Analysis

The Project Team went through a structuring exercise to develop a recommended approach. The focus was to identify a delivery model that would:

- Meet the goals specified for this initiative (open, ubiquitous fiber optics to every home and business, with opportunity for competition over the network)
- Create a broadband market that provides long-term best value for taxpayers, users, and the City

[12] We apply an uncertainty of +/- 20 percent based on our experience and typical industry practice.

- Create a feasible business case for the project
- Create a marketable structure that can be financed

The Project Team considered three delivery models: purely public, purely private, and public–private partnership (P3).

1.2.1 Fully Private or Public Delivery Models Do Not Satisfy the City's Goals

The Project Team first evaluated the two polar options that have existed as broadband delivery models in the past: either fully-private or fully-public networks.[13]

Private broadband investment is resulting in new broadband competition in unevenly distributed ways across San Francisco. AT&T is upgrading its network to fiber in certain areas, but not, to our knowledge, on a ubiquitous basis. Comcast has recently upgraded its residential service footprint with DOCSIS 3.1 electronics that will allow speeds of up to a gigabit in the downstream direction, but this network still relies on coaxial cable for distribution and the gigabit service is priced in excess of $150 per month.[14]

On the competitive side of the industry, a new class of competitors including Sonic, Webpass, and Monkeybrains is making important investments in fiber and other technologies in some San Francisco neighborhoods, but these new networks are available only in certain areas and to certain buildings or consumers.

Both incumbents and competitors deploy new or upgraded infrastructure on a limited basis, focused on geographic areas where costs are lowest and revenues and return on investment are likely to be highest. As a result, most network investments are generally uneven across the City, with some San Francisco residents offered far better options than others, and many unable to afford the higher-capacity options. In addition, none of the incumbent or competitive providers in San Francisco operates its network on an open basis, allowing its competitors to reach consumers over its infrastructure.

We therefore conclude that the private sector is not currently poised to deliver the City's stated goals of ubiquitous, open, fiber-based service throughout San Francisco.

A purely public network could meet goals for ubiquity and openness, but the City has raised a number of areas of concern, including internal capacity to build and operate a new utility; public

[13] The public and private delivery models are summarized and discussed in more detail in Sections 3 and 4 below.

[14] Comcast representatives told CTC and City staff in a September 2017 meeting that the residential gigabit product (with 35 Mbps upstream) is offered at the "everyday price" of $160 per month, plus a modem purchase of $200 or $10 per month. Introductory, promotional pricing for the same product is $70 per month, plus the cost of equipment, based on a 24 month contract. Gigabit service will be available to businesses by the end of the year, but at higher pricing.

finance challenges in light of the many important project vying for public financing, and the substantial risks of proceeding on a purely public basis.

Indeed, in a purely public model, the City could meet its policy goals but would assume all project risk, including construction, operations, performance, customer service, demand and market considerations, and technology change. A parallel set of concerns relates to public sector capacity and interest in building, maintaining, and operating a communications utility, including the particular challenge of operating a communications network in an area of the country where hiring professionals in that field is most competitive.

And the market risk assumed by the City in a purely public model is considerable. To put the initiative into context of other city-led efforts and the larger broadband market, we developed a financial model for a traditional municipal network in which San Francisco would build, own, and operate the network, and provide retail services to residents and businesses.[15] This model suggests that the network would require a take rate of 45 percent (assuming the lower cost estimate) to 53 percent (assuming the higher cost estimate) to break even, both of which represent very aggressive goals.[16] Few municipal networks have managed to reach this level of penetration.

1.2.2 Application of P3 Delivery to Broadband Involves Novel Questions and Opportunity

P3 delivery represents a logical alternative opportunity for deployment, maintenance, and operations of ubiquitous fiber. It enables the City to own the core infrastructure and use it to achieve policy goals such as competition and equity—at the same time as shifting some risk to the private sector and leveraging private sector delivery capabilities.[17]

In a formal P3 structure, a selected private partner takes responsibility for some combination of design, construction, financing, operations, and maintenance,[18] at least partially funded or guaranteed by the public partner over the period of the concession.

Formal P3s have emerged in the broadband sector in other parts of the world where infrastructure is more frequently delivered through a P3 than in the United States. In the past few years, a range of creative broadband P3 structures has started to evolve in the United States. The nature of these P3s range from public sector facilitation of private broadband investment

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[15] The model is discussed in detail in Section 3 below.

[16] Take-rate is one of the traditional metrics for evaluating the performance of broadband networks, both public and private.

[17] The P3 delivery model is summarized and discussed in more detail in Sections 5-8 below.

[18] "Financial Structuring of Public–Private Partnerships (P3s)," U.S. Department of Transportation, 2013 http://goo.gl/gCJIZK (accessed February 2017).

(through process, regulation, and economic development incentives) to public deployment of infrastructure for use by the private sector.

What is novel about the Fiber for San Francisco Initiative is that it contemplates application of the "classic" P3 structure to a broadband network that would reach 100 percent of the homes and businesses in the community.

The application of P3 structures and principles to broadband is not straightforward. Formal P3s developed as an effective tool for governments to shift appropriate risks to the private sector in infrastructure areas that have traditionally been entirely the responsibility of government, such as transportation, public transit, prisons, and water and sewer utilities.

In contrast, in the broadband environment, application of a P3 involves an opposite set of relationships. In an area that traditionally, in the United States, has been primarily the province of private companies, broadband P3s contemplate allocation of some risk and responsibility to the public sector.

While government has long had a critical and insufficiently acknowledged role in shaping the broadband market, that role has often been limited to regulation, deregulation, preferred access to assets, and so on—as well as certain kinds of public subsidy for private networks such as through the Federal Communications Commission's High Cost and Connect America Funds. The P3 structure contemplates assumption of the type of financial risk that traditionally has been the domain of private investors—in a somewhat competitive marketplace with constantly shifting services and consumer preferences.

1.2.3 The Classic P3 Model Applied to Broadband Creates Some Challenges

To understand how a formal P3 can be structured for FTTP, which has never before been done in the United States, we first considered the "classic" model and then developed alternative models that we believe will better suit this new class of projects.

In the Classic P3 Model, the City would negotiate a long-term contract with a P3 broadband concessionaire who would design, construct, finance, operate, and maintain the network. The City would sponsor and own the infrastructure,[19] but the concessionaire would control access to it. The City would achieve some of its primary goals under this model. The City's contract with the concessionaire would also shield the City from some long-term project risks. The concessionaire would hold the long-term performance risks associated with the project, as well as some portion of the construction and market risk.

[19] The term sponsor comes from the term "Project Sponsor" which is the entity with the overall accountability for the project. In this case, the City of San Francisco is the sponsor of the project. The City has ultimate responsibility, and is accountable to the public/taxpayers.

However, in terms of the principles that guide our financial and strategic analysis, the Classic P3 Model raises concerns. First, a single concessionaire with a long-term concession (as in a toll road scenario) would not deliver the open, competitive environment the City seeks. Second, uncertain revenues increase risk to the project business case. Potential commercial revenues under this model are highly uncertain, due both to the unpredictable nature of broadband equipment and network technologies and the maturity of the San Francisco market. Transferring this revenue risk to the concessionaire would require the City to pay a very high cost of financing. Third, risk mitigation is required to attract investors and financiers. Due to the highly uncertain revenue streams in this model, it is unlikely that financiers and investors will be willing to invest unless they would have a quasi-monopoly, including rate-setting powers, and/or some type of contribution from the City (e.g., a guarantee, risk-sharing mechanism, or partial payment) to mitigate risk.

1.3 Potential P3 Models: Dual P3s (Dark Fiber and Lit Services) or a Single Dark Fiber P3

We then developed two alternative P3 approaches to meet the City's goals, one that contemplates P3 delivery of both dark fiber and lit services (a "Dual P3 Model") and one that contemplates a dark fiber model only ("Single Dark Fiber P3 Model").[20]

1.3.1 Potential Dual P3 Model: Separate the Dark Fiber and Lit Service P3s

The recommended Dual P3 Model recognizes that the most critical challenge in the Classic P3 Model is the disparity between the risk profiles associated with the dark fiber investment and the provisioning of lit services. Combining these two risk profiles within one P3 makes the Classic P3 Model highly challenging from the perspective of developing a sustainable business model.

Our approach is to create as much market competition as possible at both the dark fiber and lit services layers. In this approach, the City's concessionaires would not enter the internet business, but rather would enable robust private sector competition.

As such, the recommended Dual P3 Model comprises two separate P3 contracts:

1. Dark Fiber P3: Includes design, build, partial finance, and operations and maintenance (O&M) of the outside plant infrastructure, including the fiber itself. This is a long-term P3 contract (likely 30 years) for dark fiber investments that includes partial public financing.

2. Lit Fiber P3: Includes equipment and O&M investments, and provision of base-level service. This is a shorter-term P3 contract (likely seven to 10 years, timed to match the useful life of most of the network equipment).

[20] This analysis is described in detail in Sections 7 and 8 below.

The Dark and Lit Fiber P3 investments can be separated because interrelationships between the two are limited. This approach results in a more explicit distinction between the dark fiber network provider and the service provider on that network, with the intent to enable more technological flexibility and competition in lit service delivery.

1.3.1.1 Financial Analysis and Modeling of Dual P3 Model

The Project Team developed a financial model for the Dual P3 structure to understand the required Connection Fee per residence, required Connection Fee per business, and expected payments to the P3 concessionaires based on cost estimates for full FTTP deployment. The analysis also sought to understand how cost and revenue variations influence these fees.[21]

Table 3 shows that a $51 per month residential Connection Fee and a $73 per month average business Connection Fee would cover all of the project costs (including the subsidy) and make the project financially feasible under the base case assumptions. Because these results are uncertain (which is typical for this stage of project development), the sensitivity analysis shows the likely range of required payments based on differing assumptions for six main variables that can affect the Connection Fees: capital costs, operations costs, contract term of the Lit Fiber P3, level of subsidy, additional revenues, and financing conditions.

Uncertainties related to capital costs are the most significant, followed by the financing uncertainties and alternative strategies regarding the subsidy for low-income residents. As the project progresses and additional analysis and information is added, these uncertainties will be reduced.[22] The sensitivity analyses found that the worst-case scenario garnered a residential Connection Fee of $67 per month, whereas the best-case scenario residential Connection Fee is $26 per month.

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[21] This analysis is based on preliminary information and assumptions as available for the project at this time, and are uncertain—which is common at this stage of project development. We expect that as more analysis is conducted on the project, and the project progresses, we will be able to refine our analysis based on more substantive information regarding expected upfront revenues, commitment of public resources, and so on. Additionally, due to the level of uncertainty, most results of the financial analysis are represented as ranges rather than exact outcomes, as appropriate.

[22] Among the questions the Project Team considered was how to structure the Lit Fiber P3 and craft an RFP for a Lit Fiber Concessionaire that would serve the City's defined principles and goals. Among other matters, the Lit Fiber approach contemplates delivery of a base level of broadband service to every San Francisco household and business; defining what that base level of service should be is the key challenge of structuring the Lit Fiber P3. In summary, the Project Team determined that provision of a lit fiber service by the City's concessionaire would create significant challenges, either through reduction in the potential commercial market (if the Concessionaire offered a high-speed product as part of the base-level service) or through inefficiency (if the Concessionaire offered a low bandwidth product that would waste the capacity of the network and entail significant cost relative to benefit). This analysis is described in detail in Section 7 below.

Table 3: Estimated Dual P3 Connection Fees

Output	Base Case	Range
Connection Fee – residential	$51 / passing / month	$26 – $67 / passing / month
Connection Fee – business (average)	$73 / passing / month	$38 – $97 / passing / month

As Table 4 illustrates, the Dark Fiber P3 Concessionaire is expected to require a $1.36 billion milestone payment at substantial completion (i.e., paid in years 2 and 3), in combination with annual availability payments of $36 million for 30 years to finance the project and cover all of the dark fiber project costs (including the subsidy) under the base case assumptions. Under the most conservative, worst-case scenario, a milestone payment of $1.63 billion in combination with annual availability payments of $45 million would cover all of the project costs.

Table 4: Estimated Dark Fiber P3 Milestone Payment and Availability Payment

Output	Base Case	Range
Dark Fiber Milestone Payment (Total)	$1.358 billion	$1.087 billion – $1.629 billion
Dark Fiber Availability Payment (Annual)	$36 million/year	$27 million/year – $45 million/year

The two-part payment approach (i.e., a milestone payment in combination with an availability payment) is intended to optimize the project's financing structure. If the City would prefer a payment structure without a milestone payment, the financing costs would be significantly higher and an annual availability payment of $129 million over 30 years would be required under the base case scenario. Under the most conservative, worst-case scenario, the required annual availability payment would be $173 million.

As Table 5 illustrates, the Lit Fiber P3 Concessionaire is expected to require a $147 million milestone payment at substantial completion, in combination with annual availability payments of $62 million, to finance the project and cover all of the lit fiber project costs (including the subsidy) under the base case assumptions.

Table 5: Estimated Lit Fiber P3 Milestone Payment and Availability Payment

Output	Base Case	Range
Lit Fiber Milestone Payment (Total)	$147 million	$123 million – $176 million
Lit Fiber Availability Payment (Annual)	$62 million/year	$42 million/year – $76 million/year

1.3.2 Potential P3 Model: Single Dark Fiber P3 Only

The Project Team also developed a second potential business structure to meet the City's goals for this initiative in which the City would not build lit services into the P3 plan but would develop a single dark fiber P3. The dark fiber structure would be designed to maximize competition through leasing of dark fiber to competing ISPs rather than through City-funded provision of competition at the lit services layers.

1.3.2.1 Benefits of Single Dark Fiber P3

So long as a market emerges for dark fiber leases that would enable new competition, a Single Dark Fiber P3 model offers greater simplicity, lower cost, and—potentially—lower risk and reduced opposition from incumbent providers that oppose the City's efforts to increase broadband competition. With a Single Dark Fiber P3, the City would spend dramatically less because it would not take on the financial commitment necessary for a Lit Fiber Concession. Developing a Single Dark Fiber P3 also reduces complexity and administrative burden for the City. Unlike lit services and equipment, dark fiber is a stable, predictable asset.

The model also removes from the City's purview network operations. Rather than determining parameters and terms for these areas of operation through the Lit Fiber PG, the City's role would be limited to the simpler dark fiber layer of the network.

The Single Dark Fiber P3 model also potentially reduces the challenges inherent in the City's work to promote competition and better broadband. Regardless of merits, City efforts to expand broadband and broadband competition have been aggressively opposed by incumbent phone and cable companies nationwide. In a dark fiber model, the City (and its Concessionaire) play no role in providing services to the public, but rather provide a dark fiber platform to enable the private sector to enter the service business. Frankly, incumbents are likely to oppose this initiative regardless of how limited the City's role is, but the customary incumbent claim of "unfair competition" from the public sector is undercut by the model.

Further, by removing the City from direct roles in shaping services, pricing, or performance standards, the Single Dark Fiber P3 preserves the full retail market for competing ISPs—rather than using a P3 to deliver some level of services to the public.

1.3.2.2 Challenges of Single Dark Fiber P3

Though simple and efficient, the Single Dark Fiber P3 model reduces options with regard to funding and to competition. Without a service delivered to every home and business, a property-related fee cannot be used for the Connection Fee to fund the project.

The competition considerations are also complex with respect to comparison between the Single Dark Fiber P3 and the Dual P3 models. While the Single Dark Fiber P3 creates unprecedented opportunity at the dark fiber layer, it also does not deliver competition as effectively as a Lit Fiber

P3 potentially can. The market, depending on how the fiber is priced, may support only one or two dark fiber lessees for the foreseeable future. In contrast, a lit network can provide very inexpensive open access to many service providers, including very small operations with modest resources, at low incremental cost. The unknowns regarding the dark fiber market also raise the question of whether the model will ensure sufficient competition emerge to support the City's affordability and digital equity goals.

1.3.2.3 Financial Analysis and Modeling of Single Dark Fiber P3

To understand the potential Connection Fee necessary to support the Single Dark Fiber P3 Model, the Project Team developed a version of the financial model for dark fiber only. The model suggests that the necessary residential Connection Fee, assuming no dark fiber revenues, will be in the range of $15 to $37 per residential passing per month, with a base case value of $28. The average business Connection Fee would be in the range of $21 to $54 per passing per month, with a base case value of $41. See Table 6.

Table 6: Estimated Single Dark Fiber P3 Connection Fees (Assuming No Additional Revenue)

Output	Base Case	Range
Connection Fee – residential	$28 / passing / month	$15 – $37 / passing / month
Connection Fee – business (average)	$41 / passing / month	$21 – $54 / passing / month

The Project Team next modeled a range of scenarios to understand how dark fiber revenues may reduce the Connection Fee necessary. Given that a dark fiber market of this type (connecting every home and business) has never been attempted in a city of the size of San Francisco, we analyzed data from two other projects in smaller cities where this model has been pioneered to understand the financial implications for San Francisco of the revenues generated in those cities.

The City of Westminster, Maryland, for example, has a 20 year contract with Ting Internet in which the city is obligated to finance and build all of the outside plant (including drops to customers' premises). Ting is leasing fiber with a two-tiered lease payment. One monthly fee is based on the number of premises the fiber passes ($6 per month per passing); the second fee is based on the number of subscribers Ting enrolls ($17 per month per subscriber).[23] In another

[23] Because Ting will pay Westminster a monthly fee of $6 for every home and business passed, Ting is financially obligated to the city from day one, even if it has no customers. This structure gives the city confidence that Ting is highly incented to sell services to cover costs. Ting will also pay the city $17 per month for each customer it serves. In later years, when Ting's revenue hits certain thresholds, Ting will pay the city a small fraction of its revenue per user. That mechanism is designed to allow the city to share in some of the upside of the network's success. In other words, the city will receive a bit of entrepreneurial reward based on the entrepreneurial risk the city is taking. Perhaps most significantly, there is also a mechanism built into the contract that ensures that the two parties are

variation on this model, Huntsville, Alabama's municipal electric utility is building a fiber network and Google Fiber is leasing fiber throughout the city to serve residences and small businesses.[24] Google Fiber's lease is for 20 years based on a rate sheet that provides for various levels of pricing based on amounts and volume. The pricing structure is complex but we estimate Google Fiber's monthly cost to be approximately $6 to $7 per month per passing.[25]

The financial model suggests that, applying the Westminster and Huntsville pricing to San Francisco at a take rate of 50 percent for residential customers and 30 percent for business customers would bring the expected Connection Fee down from $28 per month without dark fiber revenues to $16 (Westminster pricing) to $22 (Huntsville pricing) per month. Our base case for additional revenues assumes a monthly per passing fee of $6 and a monthly per subscriber fee of $6 at a take rate of 50 percent for residential customers and 30 percent for business customers, resulting in a residential Connection Fee in the Single Dark Fiber P3 model of $20 per month.

1.3.3 Upfront Securing Revenues

The key uncertainty in the financial analysis of this initiative is the revenue potential. Whereas the analysis of passing fee and customer fee structures provide a rough indication, the revenue potential of the initiative is inherently uncertain. This is why a pre-lease of access to the network in advance of the procurement and construction is important. Such an approach would not only reduce the Connection Fee that is required to make the initiative financially feasible, but would also create more robust cash flow and thereby enhance the ability to finance the initiative. Similar pre-lease or pre-sale agreements are common in other sectors, such as real estate and power.

The Project Team prepared a simple sensitivity analysis that shows that an annual revenue stream of $25 million would reduce the required Connection Fee from $51 to $44 per month under the Dual P3 Model and from $28 to $22 per month under the Single Dark Fiber P3 Model. (Note that this is an illustration only; the $25 million figure is not based on research and is highly uncertain.) These results emphasize the significance of the upfront securitization of revenues.

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truly sharing risk around the financing of the outside plant infrastructure. In any quarter in which Ting's financial obligations to the city are insufficient to meet the city's debt service, Ting will pay the city 50 percent of the shortfall. In subsequent quarters, if Ting's fees to the city exceed the debt service requirements, Ting will be reimbursed an equivalent amount. This element of the financial relationship made the deal much more attractive to the city because it is a clear demonstration of the fact that its private partner is invested with it.

[24] Huntsville is not financing or building the drops to the home; it's obligation to Google is to provide fiber that passes the premises only.

[25] In contrast, Ting's obligations to Westminster are based in part on how much fiber it uses and in part on how many customers it secures and revenues it generates. As a result, Westminster will have less predictability and certainty about its revenues from Ting, but has the potential to share in upside in the event that Ting is very successful in that market.

1.3.4 Innovative, Lower-Cost Financing Structure

Both P3 models assume that the Dark Fiber P3 will be financed in an innovative, efficient way to reduce the total financing costs to the City. We anticipate that the City can largely convert its dark fiber debt from P3 capital (which is customarily quite expensive relative to public finance) to revenue bonds. The revenue bonds would be secured with the Connection Fee revenues, which are likely to be a sufficiently robust stream of revenues to support a lower-cost revenue bond. We recommend that the revenue bond not entirely replace P3 capital, but rather that the City include some P3 capital to ensure the concessionaire's commitment and continuous incentive to perform. In this way, the City may be able to significantly reduce its finance costs, while still enjoying the benefits of P3 financing related to effective risk transfer and performance incentives. Any long-term dark fiber revenues that the City is able to secure in advance can further support this financing structure.[26]

1.3.5 Subsidy of Connection Fee for Lower Income San Franciscans

A P3 that involves assessment of a fee or tax to residences and businesses would impose some burden on lower income San Franciscans. In consultation with City staff, CTC analyzed the potential P3 structures with consideration of subsidizing the Connection Fee for some San Francisco households. Under the base case assumptions a subsidy would be offered to 15 percent of households.

1.4 Procurement Strategy and Recommendations

Both of the alternative broadband P3 delivery models discussed above require a procurement strategy that is grounded in the traditional P3 process—but customized and expanded to account for both the unique aspects of this effort and the P3 investment community's lack of familiarity with the broadband sector.[27] And the unique nature of broadband as an asset class also requires adding new features to the procurement process, including securing offtake agreements or pre-lease of access to the network in advance of the procurement. We recommend the following elements for a P3 procurement process:

1. **Industry sounding**. A pre-procurement industry sounding will clarify and market the project and proposed P3 structure—generating market appetite and soliciting inputs to further refine the structure. The industry sounding could include "industry day" interactions or one-on-one interactions with interested parties.

2. **Pre-procurement sale of dark fiber leases**. A pre-procurement sale for dark fiber and other network capacity in advance of the P3 RFP will quantify and secure revenues that would otherwise be speculative; this will enable (1) bids with lower requirements for City

[26] A recommendation to secure dark fiber revenues in advance of network construction is described in Section 9.1.

[27] Detailed discussion of a procurement and fiber leasing strategy is in Section 9 below.

funding/guarantees, and (2) a more competitive bidding process in which all bidders can account for these revenue streams. This sale of capacity also has the potential to concretize the opportunity, for investors, service providers, and the public.

3. **Two P3 procurements, if the Dual P3 structure is adopted.** Separate P3 procurements (one for dark fiber and other outside plant infrastructure, another for equipment, operations, and services) should be run partially in parallel to enable adjustments as necessary and efficiency.

4. **Integration of RFP development and industry consultation/negotiations.** Although the City has been contemplating an RFP development process followed by negotiations with one or more selected bidders, we recommend integrating these phases and building multi-step consultation with selected bidders into a more extensive process of RFP development and vetting. This process—which should be more extensive than in other P3 sectors, given the novelty of this effort—will enable the necessary level of interaction with potential bidders, giving the City opportunity to refine these complex procurements, while enabling the bidders to further understand and craft bids for this new, unfamiliar asset class.

Within this framework, we also recommend that the procurement process should:

- **Begin as early as possible in order to gather industry feedback**. A key risk for this project is that there will be a mismatch between the level of funding pre-approved, and what bidders will propose during the procurement process. In an ideal situation, bidders would be selected in advance of final funding approvals, enabling a firm understanding of the level of financial commitment needed. Starting engagement with potential bidders through an industry sounding, and initiating the RFQ and RFP process as early as possible in order to obtain some level of interaction and information from bidders, will help provide as much information as is feasible at that early stage of the process.

- **Build in sufficient time and flexibility.** A procurement timeline that accounts for the pioneering and singular nature of this effort will build in sufficient time and flexibility to vet all elements of the bid requirements. In the event the City elects to pursue the dual P3 structure, an extended timeline will likely also be required.

- **Apply P3 procurement best practices.** Even though this procurement will be the first-of-its-kind, several P3 procurement best practices can be applied. These include shortlisting three or four qualified bidders in the RFQ phase, and communicating with bidders prior to bid submission in the draft RFP phase.

2 FTTP Design and Cost Estimate

CTC's engineers prepared a network design and cost estimates for deploying a gigabit FTTP network to all homes and businesses in the City. We developed cost estimates for two FTTP deployment approaches to provide data relevant to assessing the financial viability of network deployment, and to developing a business model for the Fiber for San Francisco Initiative:

- **A "lit" FTTP network**, including the costs to deploy FTTP outside plant infrastructure, as well as all electronics, consumer drops, and customer premises equipment (CPE); this estimate shows the total capital costs (by the City or the City and partners) to build an FTTP network to support a ubiquitous 1 Gbps (gigabit per second) data service

- **A "dark" FTTP network**, including the cost to deploy just the FTTP outside plant; this is the total capital cost for the City to build a dark FTTP network for use by one or more entities, including private internet service providers

The network design and cost estimates are based on data and insight gathered by CTC engineers in discussions with City stakeholders and an extensive field and desk survey of candidate fiber routes.

2.1 Summary of Cost Estimates

The cost estimates are based on a combination of aerial and underground construction, and a range of potential construction scenarios. The low-cost scenario assumes directional boring throughout the City using test pitting to minimize outages to existing utilities. The high-cost scenario requires high levels of surface restoration (i.e., complete sidewalk replacement).

2.1.1 Lit FTTP Cost Estimate

We estimate the lit FTTP network deployment will cost $1.9 billion,[28] inclusive of outside plant construction labor, materials, engineering, permitting, pole attachment licensing, network electronics, drop installation, CPE, and testing.[29] We estimate the average construction cost per passing[30] is $2,050. These costs are summarized in Table 7.[31]

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[28] This is the High-Cost Scenario as described below.

[29] Because the City directed that the analysis assume the network will be deployed in a "utility" model, the estimated total cost breakdown assumes that 100 percent of residents and businesses will subscribe to the service. In a delivery model in which residents decide whether or not to subscribe to service, this market penetration rate or "take rate" would be less than 100 percent, and some network deployment costs would be less as a result.

[30] The passing count includes individual single-unit buildings and units in multi-dwelling and multi-business buildings as single passings. In larger MDUs, the cost estimate assumes that existing wiring will be used to serve the units. We assume that each unit in large MDUs will cost $500.

[31] This is the High-Cost Scenario as described below.

Table 7: Estimated Lit FTTP Cost[32]

Cost Component	Low-Cost Scenario	High-Cost Scenario
Outside Plant	$700 million	$760 million
Central Network Electronics	112 million	112 million
FTTP Service Drop and Lateral Installations	680 million	740 million
Customer Premises Equipment	290 million	290 million
Total Estimated Cost:	$1.8 billion	$1.9 billion

Actual costs may vary due to factors that cannot be precisely known until the detailed design is completed, or until construction commences. These factors include: 1) costs of private easements, 2) utility pole replacement and make-ready costs, 3) variations in labor and material costs, 4) surface restoration, and 5) the City's operational and business model. We have incorporated suitable assumptions to address these factors based on our experiences in similar markets.

The outside plant construction landscape in the City has changed since we last estimated construction costs for San Francisco FTTP in 2009. Since then more providers have entered the market, which means more attachers on the utility poles and more conduit in the ground. New providers mean space that was originally available for the City to install fiber is no longer there, while costs for make-ready and underground conduit installation have increased. Further, new surface restoration standards will increase the cost of underground construction and the amount of time needed to construct the network. Utility pole replacement costs will increase, too, because taller poles will be needed in many locations to support the existing attachers and new City fiber. And existing poles continue to age—increasing the number of replacements needed. All of these changes increase the cost of outside plant construction.

2.1.2 Dark FTTP Cost Estimate

We estimate that a dark FTTP network deployment will cost $1.5 billion,[33] inclusive of outside plant construction labor, materials, engineering, permitting, pole attachment licensing, and lateral drop and materials. This estimate does not include any electronics or subscriber equipment. Cost components are described in Table 8.

[32] We apply an uncertainty of +/- 20 percent based on our experience and typical industry practices.

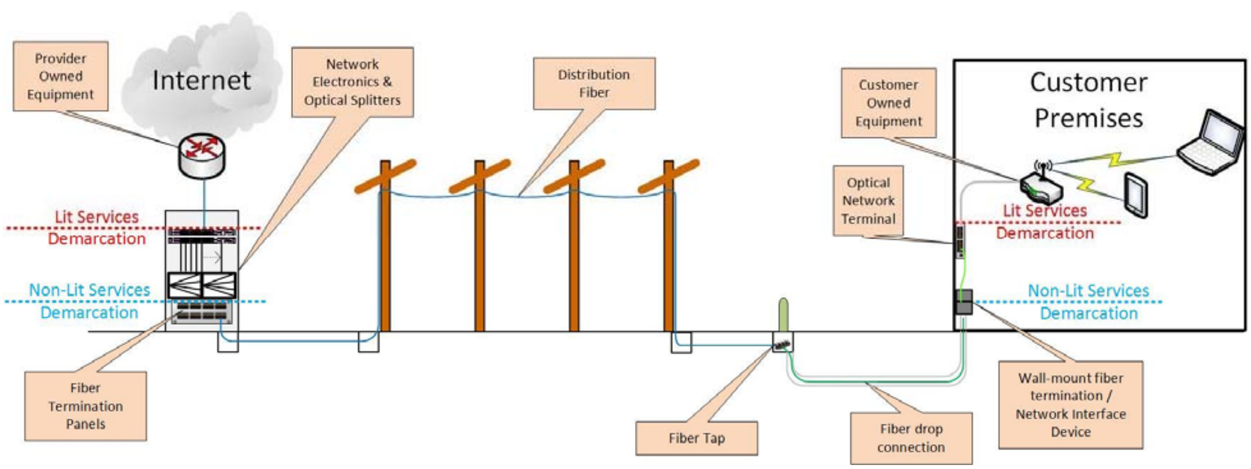
[33] This is the High-Cost Scenario as described below.

Table 8: Estimated Dark FTTP Cost34

Cost Component	Low-Cost Scenario	High-Cost Scenario
Outside Plant	$700 million	$760 million
FTTP Service Drop and Lateral Installations	680 million	740 million
Total Estimated Cost:	$1.4 billion	$1.5 billion

The dark fiber estimate assumes that the City or its partner constructs and owns the FTTP infrastructure up to a demarcation point (a network interface device) at each residence and business, and that the dark fiber backbone, distribution, and drop fiber are then lit by a separate entity. The lit fiber entity would be responsible for all network electronics and customer premises equipment (CPE)—as well as network sales, marketing, and operations. The network architecture could support multiple entities using fiber assets on a leased basis or other basis.

Figure 1: Demarcation Between City and Partner Network Elements in Lit and Dark Models



2.2 Approach to Technical Analysis

CTC engineers performed a range of analytical tasks to gather data and insight for the FTTP design.

2.2.1 Field Survey

A CTC outside plant engineer performed a preliminary survey of San Francisco onsite and via Google Earth Street View to develop estimates of per-mile cost for aerial fiber in the communications space, and per-mile costs for underground fiber (where poles are not available).

[34] We apply an uncertainty of +/- 20 percent based on our experience and typical industry practices.

The engineer reviewed available green space, necessary make-ready on poles, and pole replacement—all of which have been factored in to the design and cost estimate.[35]

Table 9 summarizes the conditions determined through our field and desk survey, with respect to three population densities we used in the cost estimation model—high, medium, and low. Make-ready and aerial construction costs will be higher in the City than other cities but will still be less expensive than underground construction.

Table 9: Field Survey Findings and Make-Ready Assumptions

	High Density	Medium Density	Low Density
Aerial Construction	20%	50%	60%
Poles per Mile	50	50	50
Moves per Pole	4	4	3
Poles Requiring Make-Ready	60%	60%	60%
Poles Requiring Replacement	10%	10%	10%
Cost Per Move	$450	$450	$450
Cost Per Pole Replacement	$35,000	$35,000	$35,000

CTC's outside plant engineer noted that the quality of the poles and pole attachments in San Francisco varied, as they do in many cities—but overall, many poles would not support an additional communications attachment without significant make-ready. While the pole lines may not be ideal for aerial construction, the cost of make-ready is still less than the cost of underground construction in the City. As such, we recommend aerial construction where pole lines exist.

The following figures illustrate existing City utility conditions observed by CTC's outside plant engineer.

[35] Green space is right-of-way typically covered in grass or sidewalk that would be less expensive to construct in than the street. Make-ready if the work needed to bring a utility pole into compliance and clear space for an additional attachment. Pole replacement is the replacement of a utility pole typically with one that is taller and/or a higher class that will support additional attachments.

Figure 2 shows a typical utility pole line along a major roadway in Bayview. The poles are crowded, which will necessitate significant make-ready.

Figure 2: Crowded Utility Pole Line in Bayview

Figure 3 shows another crowded pole line in Excelsior.

Figure 3: Utility Pole Requiring Make-Ready in Excelsior

Figure 4 shows a pole line in Richmond that will require extensive tree trimming.

Figure 4:Tree Trimming Required on Richmond Pole Line

Figure 5 shows a clean pole line with relatively little required make-ready in Silver Terrace.

Figure 5: Clean Pole Line in Silver Terrace

2.2.2 Subsurface Investigations

CTC engineers met with the City and various service providers to discuss their experiences with underground construction. The City's density and age make it extremely difficult and expensive to construct underground facilities, especially in older neighborhoods.

2.2.2.1 Directional Boring

Directional boring involves the digging of small test pits, generally at locations where pull boxes will be installed, and drilling hundreds of feet between these pits. The boring equipment then pulls the conduit back through the bore path as it is removed.

To minimize damaging underground utilities, the City is developing new regulations that will require companies that use directional boring to take extra precautions prior to construction. The new requirements include reviewing City-provided utility maps, performing pre-inspection of the existing utilities, and test-pitting the crossings of all known and assumed utilities.[36] These impending requirements are in response to a recent undergrounding project in which City utilities were hit by a company that had used directional boring as the construction method.

Even with the new regulations, however, there is still risk involved with this type of construction. The City has identified cases where undocumented sewer service lines have been damaged because they enter homes and businesses at shallower depths than the City's current standard.

2.2.2.2 Microtrenching

The City is contemplating a microtrenching policy. Microtrenching cuts a narrow trench (i.e., one to two inches wide) into roadway or sidewalk pavement. The contractor then installs narrow conduits, into which specialized fiber is blown. Because microtrenching minimizes the amount of surface restoration required, it can be a cost-effective alternative to traditional underground construction. This approach is widely used in New York City, Boston, and Vancouver, British Columbia, especially by wireless service providers.

However, because microtrenching requires a trench 12 to 18 inches[37] deep into the sidewalk, a contractor could still hit existing service lines to homes and businesses. Also, under the City's proposed rules, microtrenching is only allowed in the sidewalk, and requires total replacement of any sidewalk slabs that are cut. These requirements will increase the cost of microtrenching construction, compared to the more common practice of only requiring the cut to be filled, or compared to microtrenching along the curb.

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[36] Our low cost estimate assumes that directional boring is used to reduce costs, with test pitting performed every 25 feet on average.

[37] The depth of the microtrenching is based on the saw blade. Deeper depths such as 18 inches are more expensive than shallower depths.

In addition, in San Francisco, there have been instances of sidewalk replacement causing cuts to existing telecommunications providers' service drops. This has occurred in places where the drops were installed at extremely shallow depths because other utilities were located deeper, below the telecommunications drops. We anticipate that a microtrenching approach that follows the City's new rules would result in construction costs between our low and high estimates.

2.2.2.3 Street Restoration

Any block of a street in San Francisco that is trenched more than 25 feet (longitudinally) requires the repaving of the entire trenched lane of that block. This requirement, while protecting the roadways, will also increase the cost of underground construction. It is partly because of this requirement that many of the City's underground areas will require construction on both sides of the road, instead of the more common technique of building fiber on one side of the right-of-way, then boring under the street to reach the residences and businesses on the other side.

2.2.2.4 Sidewalk Restoration

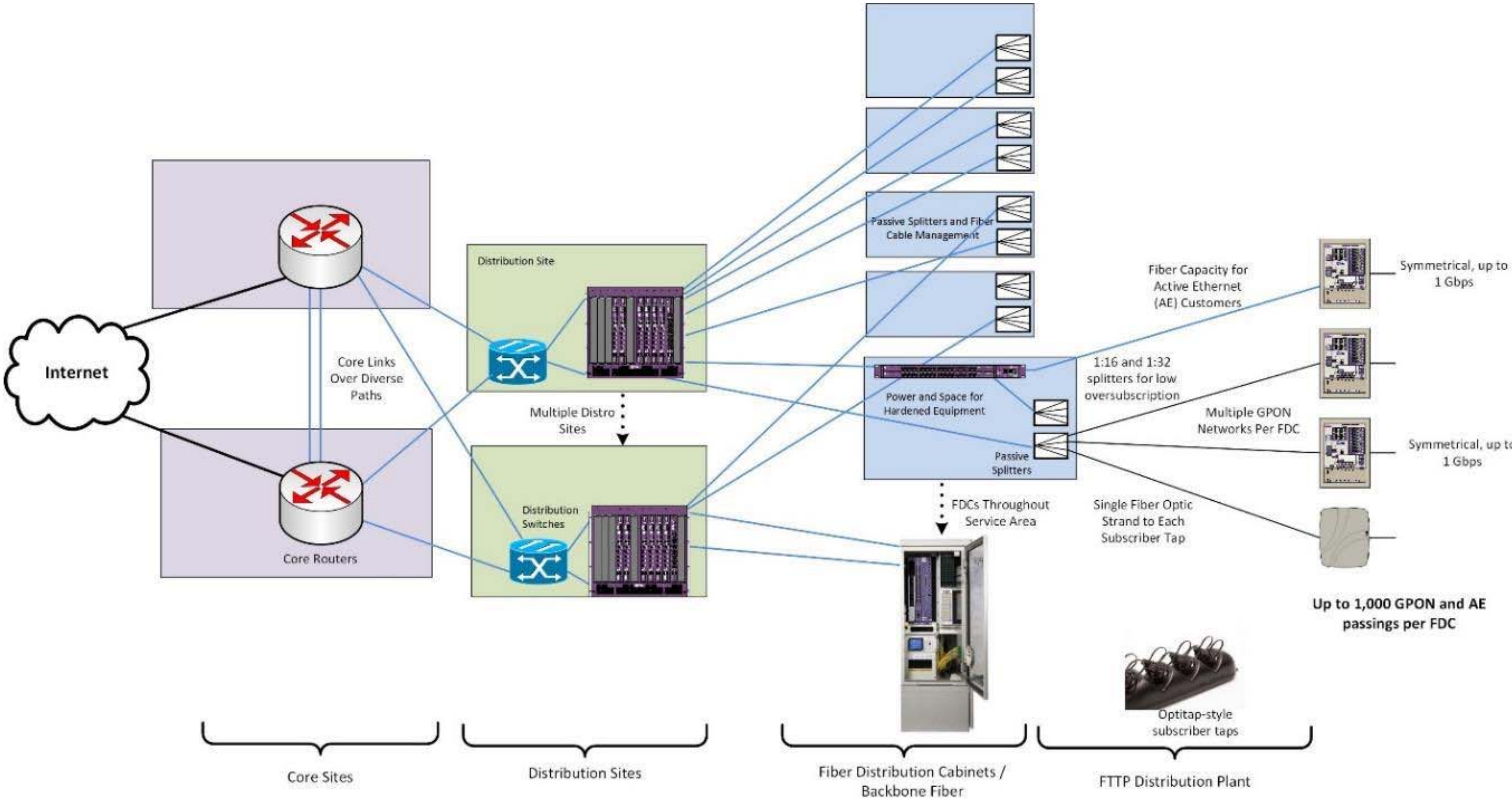
If the City or a dark fiber partner were to build the FTTP network in adherence to the City's current sidewalk restoration standards, which require replacement of each disturbed concrete slab, the project would result in the full rebuild of most of the City's sidewalks in underground construction areas. This large-scale rebuild should be considered one of the main outcomes of the project, if not the primary one. The sheer amount of underground construction required to build the network, combined with the sidewalk restoration requirements, would result in an amount of sidewalk replacement equivalent to that of a large-scale capital improvement project.

The City could view the sidewalk replacement costs as a separate capital improvement project implemented concurrently with the fiber build. At an estimated cost of $150 per concrete slab, sidewalk restoration would account for approximately $100 million of the estimated outside plant and drop costs. Additional capital improvement money could be used at the same time to further improve the streetscape by adding ramps at corners, repairing street curbs, installing tree boxes, replacing street signs, and so on.

2.3 FTTP Network Design

The architecture of the physical plant determines the network's scalability for future uses and how the plant will be operated and maintained; the architecture is also the main determinant of the total cost of the deployment, because outside plant is both the most expensive part of the network and the longest lasting. Figure 6 (below) shows a logical representation of the high-level FTTP network architecture we recommend in San Francisco. This design is open to a variety of architecture options. The drawing illustrates the primary functional components in the FTTP network, their relative position to one another, and the flexibility of the architecture to support multiple subscriber models and classes of service.

Figure 6: High-Level FTTP Architecture



The recommended architecture is a hierarchical data network that provides critical scalability and flexibility, both in terms of initial network deployment and its ability to accommodate the increased demands of future applications and technologies. The characteristics of this hierarchical FTTP data network are:

- Capacity – ability to provide efficient transport for subscriber data, even at peak levels
- Availability – high levels of redundancy, reliability, and resiliency; ability to quickly detect faults and re-route traffic
- Failsafe operation – physical path diversity to minimize operational impact resulting from fiber or equipment failure
- Efficiency – no traffic bottlenecks; efficient use of resources
- Scalability – ability to grow in terms of physical service area and increased data capacity, and to integrate newer technologies
- Manageability – simplified provisioning and management of subscribers and services
- Flexibility – ability to provide different levels and classes of service to different customer environments; can support an open-access network or a single-provider network; can provide separation between service providers on the physical layer (separate fibers) or logical layer (separate VLAN or VPN providing networks within the network)
- Security – controlled physical access to all equipment and facilities, plus network access control to devices

This architecture offers the scalability necessary to meet long-term needs. It is consistent with best practices for an open-access network model that might potentially be required to support multiple network operators, or at least multiple Retail Service Providers requiring dedicated connections to certain customers. This design would support a combination of Gigabit Passive Optical Network (GPON) and direct Active Ethernet services (with the addition of electronics at the fiber distribution cabinets), which would enable the network to scale by migrating to direct connections to each customer, or reducing splitter ratios, on an as-needed basis.

The design assumes placement of manufacturer-terminated fiber tap enclosures within the right-of-way or easements, providing watertight fiber connectors for customer service drop cables and eliminating the need for service installers to perform splices in the field. This is an industry-standard approach to reducing both customer activation times and the potential for damage to distribution cables and splices. The model also assumes the termination of standard lateral fiber connections within larger multi-tenant business locations and multi-dwelling units (MDU).

2.3.1 Network Design

The network design and cost estimates assume the City or its dark fiber partner will:

- Identify and procure space at two core facilities to house network electronics and provide backhaul to the internet
- Utilize existing City land to locate 10 distribution hub facilities with adequate environmental and backup power systems to house network electronics
- Construct fiber optics to connect core sites to distribution hubs in a backbone ring
- Construct additional backbone fiber to connect the distribution hubs to fiber distribution cabinets (FDC)
- Construct fiber optics from the FDCs to each residence and business (i.e., from termination panels in the FDC to tap locations in the right-of-way or on City easements)
- Construct fiber laterals into large, multi-tenant business facilities and MDUs

Leveraging the City's conduit and fiber resources could decrease the costs associated with both constructing a backbone and identifying locations to house electronics that are near the City's existing resources. Given the high cost of construction in many areas of the City, using existing conduit may provide a noticeable impact on the cost of construction. However, for a project of this magnitude, the cost savings are likely within the range of our projected contingency.

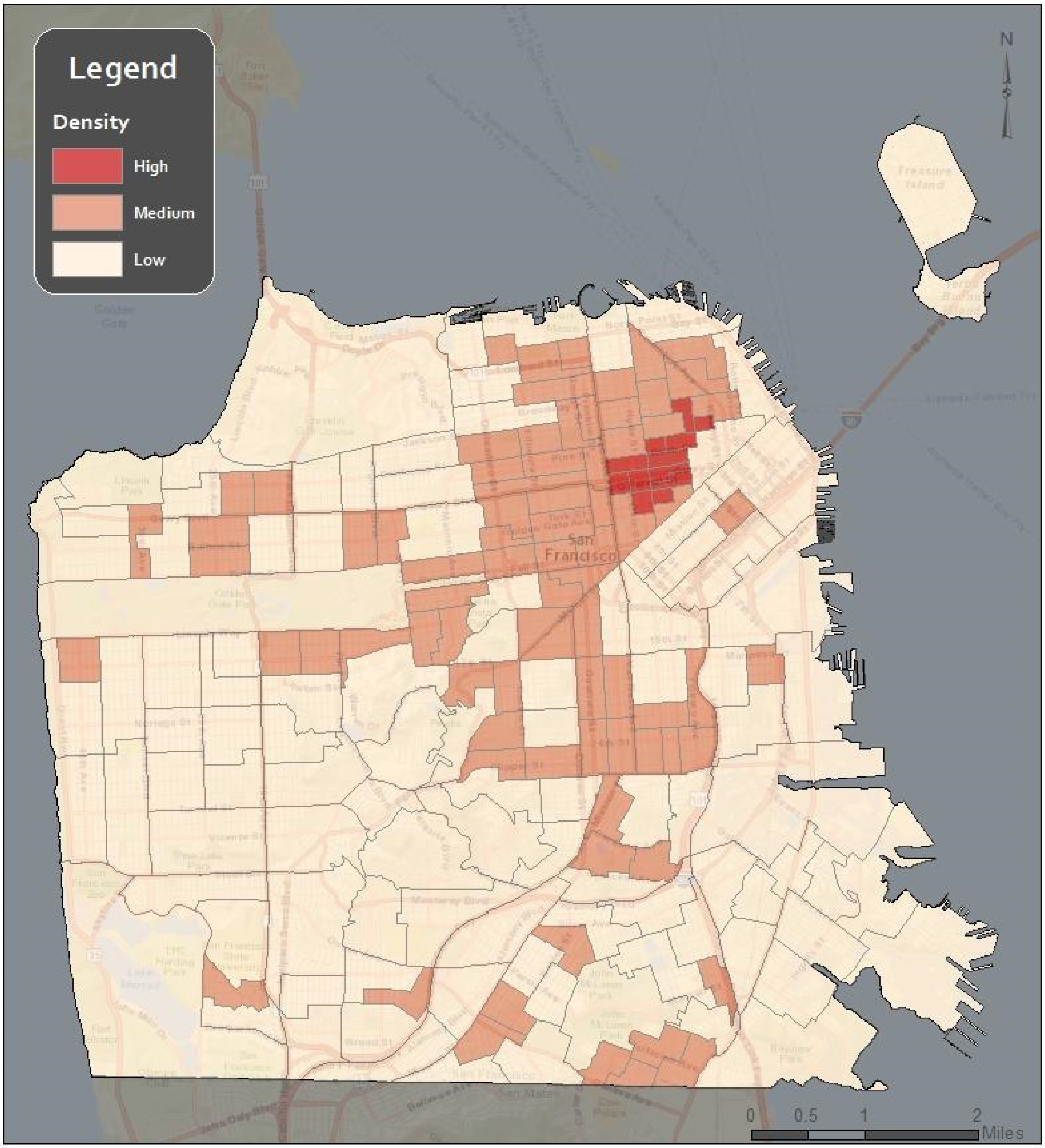
The FTTP network and service areas, depicted in Figure 7 (below), were defined based on the following criteria:

- Design targets 512 passings per FDC
- Service areas were defined by passing density and existing utilities and are broken into the categories of high, medium, and low densities
- Multiple FDCs serve each service area
- FDCs are suitable to support hardened network electronics, providing backup power and an active heat exchange[38]
- Distribution plant avoids crossing major roadways, bridges, and railways

[38] These hardened FDCs reflect an assumption that the City's operational and business model will require the installation of provider electronics in the FDCs that are capable of supporting open access among multiple providers. We note that the overall FTTP cost estimate would decrease if the hardened FDCs were replaced with passive fiber distribution cabinets (which would house only optical splitters) and the providers' electronics were housed only at hub locations. Includes costs associated with the Surface Mounted Facilities Ordinance.

Coupled with an appropriate network electronics configuration, this design serves to greatly increase the reliability of fiber services provided to customers compared to that of more traditional cable and telephone networks. The backbone design minimizes the average length of non-diverse distribution plant between the network electronics and each customer, thereby reducing the probability of service outages caused by a fiber break.

Figure 7: FTTP Service Areas



The access layer of the network, encompassing the fiber plant from the FDCs to the customers, dedicates a single fiber strand from the FDC to each passing (potential customer address). This traditional FTTP design allows either network electronics or optical splitters in the FDCs. See Figure 8 below for a sample design.

Figure 8: Sample FTTP Access Layer Design

2.3.2 Network Core and Hub Sites

The network core sites link the FTTP network to the public internet and deliver all services to end users. The proposed network design includes two core locations, based on the network's projected capacity requirements and the need for geographical redundancy (i.e., if one core site were to fail, the second core site would continue to operate the network).

The location of core network facilities also provides physical path diversity for subscribers and all upstream service and content providers. For the design and cost estimates, we assume that the City's core sites will be housed in secure locations with diverse connectivity to the internet and the City's existing fiber optic network.

The core locations in this plan will house providers' Operational Support Systems (OSS) such as provisioning platforms, fault and performance management systems, remote access, and other operational support systems for FTTP operations. The core locations are also where any business partner or content / service providers will gain access to the subscriber network with their own point-of-presence. This may be via remote connection, but collocation is recommended.

The core locations are typically run in a High Availability (HA) configuration, with fully meshed and redundant uplinks to the public internet and/or all other content and service providers. It is imperative that core network locations are physically secure and allow unencumbered access 24x7x365 to authorized engineering and operational staff.

The operational environment of the network core and hub locations is similar to that of a data center. This includes clean power sources, UPS batteries, and diesel power generation for survival through sustained commercial outages. The facility must provide strong physical security, limited/controlled access, and environmental controls for humidity and temperature. Fire suppression is highly recommended.

Equipment is to be mounted securely in racks and cabinets, in compliance with national, state, and local codes. Equipment power requirements and specification may include -48 volt DC and/or 120/240 volts AC. All equipment is to be connected to conditioned/protected clean power with uninterrupted cutover to battery and generator.

For the cost estimate, we assumed that the core facilities would be located in leased data centers and distribution hubs will be located at existing City facilities with land for a telecommunications shelter. The square footage needed depends on the business model, however we estimated 100 square feet needed per core site and 200 square feet needed per hub site to be able to support multiple service operators. A network supporting multiple service providers requires more space than a single service provider, but less space at the core and hubs may limit future network scalability.

2.3.3 Distribution and Access Network Design

The distribution network is the layer between the hubs and the fiber distribution cabinets (FDCs, which provide the access links to the taps). The distribution network aggregates traffic from the FDCs to the core. Fiber cuts and equipment failures have progressively greater operational impact as they happen closer to the network core, so it is critical to build in redundancies and physical path diversities in the distribution network, and to seamlessly re-route traffic when necessary.

The distribution and access network design proposed in this report is flexible and scalable enough to support two different architectures:

1. Housing both the distribution and access network electronics at the hubs, and using only passive devices (optical splitters and patches) at the FDCs, or

2. Housing the distribution network electronics at the hubs and pushing the access network electronics further into the network by housing them at the FDCs

By housing all electronics at the hubs, the network will not require power at the FDCs. Choosing a network design that only supports this architecture may reduce costs by allowing smaller, passive FDCs in the field. However, this architecture will limit the redundancy capability from the FDCs to the hubs.

By pushing the network electronics further into the field, the network gains added redundancy by allowing the access electronics to connect to the hub sites. In the event one hub has an outage, the subscribers connected to the FDC would still have network access. Choosing a network design that only supports this architecture may reduce costs by reducing the size of the hubs.

Selecting a design that supports both models would allow the City to accommodate many different service operators, their network designs, and various network technologies. This design would also allow service providers to start with a small deployment (i.e., placing electronics only at the hub sites) and to grow by pushing electronics closer to their subscribers.

2.3.3.1 Access Network Technologies

FDCs can sit on a curb, be mounted on a pole, or reside in a building. This model recommends installing sufficient FDCs to support higher than anticipated levels of subscriber penetration. This approach will accommodate future subscriber growth with minimal re-engineering. Passive optical splitters are modular and can be added to an existing FDC as required to support subscriber growth, or to accommodate unanticipated changes to the fiber distribution network with potential future technologies.

The FTTP design also includes the placement of indoor FDCs and splitters to support MDUs. This would require obtaining the right to access the equipment for repairs and installation in whatever timeframe is required by the service agreements with the customers. Lack of access would potentially limit the ability to perform repairs after normal business hours, which could be problematic for both commercial and residential services.

In this model, we assume the use of GPON electronics for the majority of subscribers and Active Ethernet for a small percentage of subscribers (typically business customers) that request a premium service or require greater bandwidth. GPON is the most commonly provisioned FTTP service—used, for example, by AT&T Fiber, Verizon (in its FiOS systems), Google Fiber, and Sonic.net.

Furthermore, providers of gigabit services typically provide these services on GPON platforms. Even though the GPON platform is limited to 1.2 Gbps upstream and 2.4 Gbps downstream for the subscribers connected to a single PON, operators have found that the variations in actual subscriber usage generally means that all subscribers can obtain 1 Gbps on demand (without provisioned rate-limiting), even if the capacity is aggregated at the PON. Furthermore, many GPON manufacturers are developing technology to support up to 10 Gbps and faster speeds as user demand increases.

GPON supports high-speed broadband data, and is easily leveraged by triple-play carriers for voice, video, and data services. The GPON OLT uses single-fiber (bi-directional) SFP modules to support multiple (most commonly less than 32) subscribers.

GPON uses passive optical splitting, which is performed inside fiber distribution cabinets (FDC), to connect fiber from the OLTs to the customer premises. With GPON service, the FDCs house multiple optical splitters, each of which splits the fiber link to the OLT between 16 to 32 customers.

Active Ethernet (AE) provides a symmetrical (up/down) service that is commonly referred to as "Symmetrical Gigabit Ethernet." AE can be provisioned to run at sub-gigabit speeds, and like GPON, easily supports legacy voice, voice over IP (VoIP), and video content. AE is typically deployed for customers who require specific service level agreements that are easier to manage and maintain on a dedicated service.

For subscribers receiving Active Ethernet service, a single dedicated fiber goes directly to the subscriber premises with no splitting. Because AE requires dedicated fiber (home-run fiber)[39] from the OLT to the CPE, and because each subscriber uses a dedicated SFP on the OLT, there is a significant cost difference in provisioning an AE subscriber versus a GPON subscriber.

[39] Home-run fiber is a fiber optic architecture where individual fiber strands are extended from the distribution sites to the premises. Home-run fiber does not use any intermediary aggregation points in the field.

The fiber plant is designed to provide Active Ethernet service or PON service to all passings. The network operator selects electronics based on the mix of services it plans to offer and can modify or upgrade electronics to change the mix of services.

2.3.3.2 Expanding the Access Network Bandwidth

GPON is currently the most commonly provisioned FTTP technology, due to inherent economies when compared with technologies delivered over home-run fiber such as Active Ethernet. The cost difference between constructing an entire network using GPON and Active Ethernet is 40 percent to 50 percent.[40] GPON is used to provide services up to 1 Gbps per subscriber and is part of an evolution path to higher-speed technologies that use higher-speed optics and wave-division multiplexing.

This model provides many options for scaling capacity, which can be done separately or in parallel:

1. Reducing the number of premises in a PON segment by modifying the splitter assignment and adding optics. For example, by reducing the split from 16:1 to 4:1, the per-user capacity in the access portion of the network is quadrupled.

2. Adding higher-speed PON protocols can be accomplished by adding electronics at the FDC or hub locations. Since these use different frequencies than the GPON electronics, no other CPE would need to be replaced.

3. Adding WDM-PON electronics as they become widely available. This will enable each user to have the same capacity as an entire PON. Again, these use different frequencies than GPON and are not expected to require replacement of legacy CPE equipment.

4. Option 1 could be taken to the maximum, and PON replaced by a 1:1 connection to electronics—an Active Ethernet configuration.

These upgrades would all require complementary upgrades in the backbone and distribution Ethernet electronics, as well as in the upstream internet connections and peering—but they would not require increased fiber construction.

2.3.3.3 Customer Premises Equipment (CPE) and Subscriber Services

In the final segment of the FTTP network, fiber runs from the FDC to customers' homes, apartments, and office buildings, where it terminates at the subscriber tap—a fiber optic housing located in the right-of-way closest to the premises. The service installer uses a pre-connectorized drop cable to connect the tap to the subscriber premises without the need for fiber optic splicing.

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[40] "Enhanced Communications in San Francisco: Phase II Feasibility Study," CTC report, October 2009, at p. 205.

The drop cable extends from the subscriber tap (either on the pole or underground) to the building, enters the building, and connects to customer premises equipment (CPE).

2.4 FTTP Cost Estimate

This section provides a summary of cost estimates for construction of a lit FTTP network to all City residences and businesses. This deployment will cost an estimated $1.9 billion,[41] inclusive of outside plant construction labor, materials, engineering, permitting, pole attachment licensing, network electronics, drop installation, customer premises equipment (CPE), and testing.

Table 10 summarizes these costs.[42]

Table 10: Estimated Lit FTTP Cost

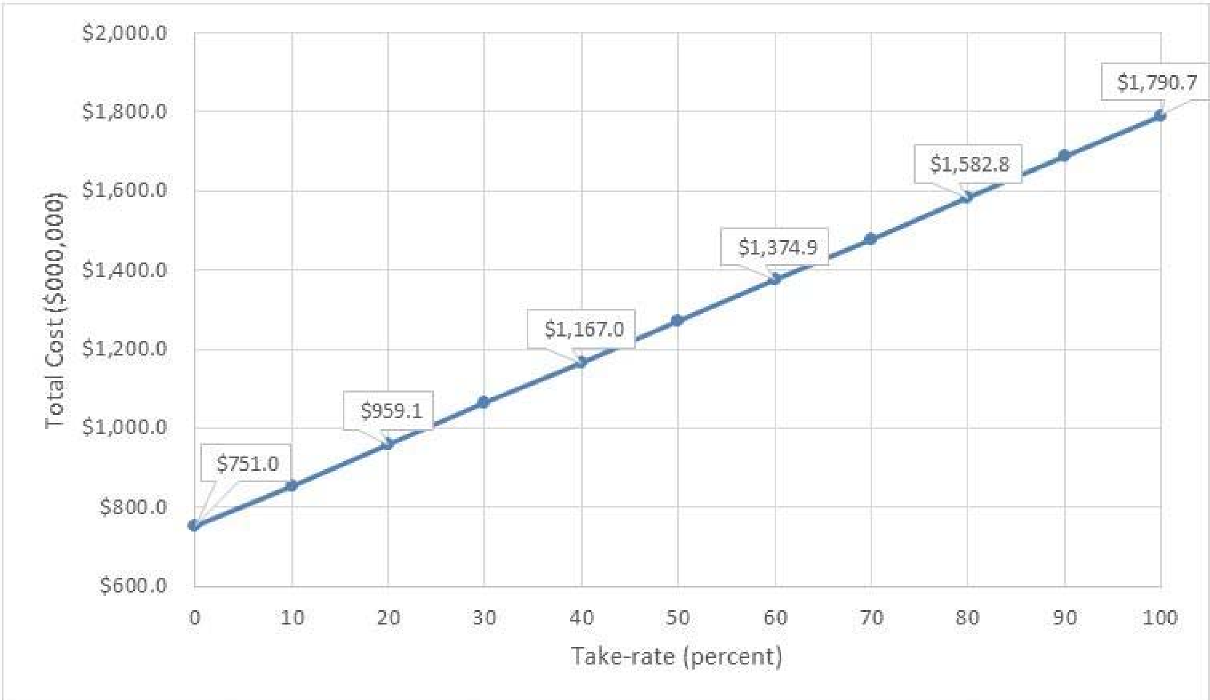
Cost Component	Low-Cost Scenario	High-Cost Scenario
Outside Plant	$700 million	$760 million
Central Network Electronics	112 million	112 million
FTTP Service Drop and Lateral Installations	680 million	740 million
Customer Premises Equipment	290 million	290 million
Total Estimated Cost:	$1.8 billion	$1.9 billion

To illustrate the potential cost if the City were to choose a model other than the utility model (i.e., if residents were to choose whether or not to buy services), Figure 9 shows the total low estimated cost with respect to potential take rates. The projected cost is roughly linear by take rate because the cost of adding additional subscribers is a fixed cost.

[41] This is the High-Cost Scenario as described below.

[42] We apply an uncertainty of +/- 20 percent based on our experience and typical industry practices.

Figure 9: Total Estimated Cost versus Take Rate (Low-Cost Estimate)



2.4.1 Outside Plant Cost Estimation Methodology

As with any utility, the design and associated costs for construction vary with the unique physical layout of the service area—no two streets are likely to have the exact same configuration of fiber optic cables, communications conduit, underground vaults, and utility pole attachments. Further, soil conditions, such as the prevalence of subsurface hard rock; the condition of utility poles and feasibility of "aerial" construction involving the attachment of fiber infrastructure to utility poles; and crossings of bridges, railways, and highways also affect costs.

In our estimates, we extrapolated the costs for strategically selected sample designs based on street mileage and passings. Specifically, we developed sample FTTP designs to generate costs per passing for three types of population densities high medium and low. The City was divided into separate areas according to Census tracks. The density of each area was determined by the total number of identified passings per the square footage and street mileage of the given census track. The number of passings for each census track was derived from address data provided by the City.

Our observations found it most prudent to estimate a range of potential costs for FTTP construction. Our low-cost model assumes directional boring with test pitting every 25 feet and minimal surface restoration.[43] The high-cost model assumes that sidewalk replacement is required for surface restoration and that conduit would be installed in underground areas as part of the sidewalk replacement.

The assumptions, sample designs, and cost estimates were used to extrapolate a cost per passing for the outside plant. This number was then multiplied by the number of passings in each area based on the City's GIS data. The actual cost to construct FTTP to every premises in the City could differ from the estimate due to changes in the assumptions underlying the model.

For example, if access to the utility poles is not granted or make-ready and pole replacement costs are too high, more of the network would have to be constructed underground—which could significantly increase the cost of construction. Alternatively, if the City could partner with a local telecommunications provider and overlash to existing pole attachments, the cost of the build could be significantly lower. Further and more extensive analysis would be required to develop a more accurate cost estimate across the entire City.

2.4.2 Components of Construction Cost Estimate

The cost components for outside plant construction include the following tasks:

- ***Engineering*** – includes system level architecture planning, preliminary designs and field walk-outs to determine candidate fiber routing; development of detailed engineering prints and preparation of permit applications; and post-construction "as-built" revisions to engineering design materials.
- ***Quality Control / Quality Assurance*** – includes expert quality assurance field review of final construction for acceptance.
- ***General Outside Plant Construction*** – consists of all labor and materials related to "typical" underground or aerial outside plant construction, including conduit placement, utility pole make-ready construction, aerial strand installation, fiber installation, and surface restoration; includes all work area protection and traffic control measures inherent to all roadway construction activities.
- ***Special Crossings*** – consists of specialized engineering, permitting, and incremental construction (material and labor) costs associated with crossings of railroads, bridges, and interstate / controlled access highways.

[43] By comparison, the cost to microtrench would likely be between the low and high costs estimate depending on the surface restoration required.

- ***Backbone and Distribution Plant Splicing*** – includes all labor related to fiber splicing of outdoor fiber optic cables.

- ***Backbone Hub, Termination, and Testing*** – consists of the material and labor costs of placing hub shelters and enclosures, terminating backbone fiber cables within the hubs, and testing backbone cables.

- ***FTTP Service Drop and Lateral Installations*** – consists of all costs related to fiber service drop installation, including outside plant construction on private property, building penetration, and inside plant construction to a typical backbone network service "demarcation" point. This cost also includes all materials and labor related to the termination of fiber cables at the demarcation point. We assumed a take rate of 100 percent for standard fiber service drops, because the "utility" model means that every residence and business will be served.

2.4.3 Outside Plant Construction Costs

In terms of outside plant, the estimated cost to construct the proposed FTTP network is $760 million, or $2,050 per passing.[44] As discussed above, the model assumes a mixture of aerial and underground fiber construction, depending on the construction of existing utilities in the area as well as the state of any utility poles and existing infrastructure. Table 11 and Table 12provide a breakdown of the estimated outside plant costs by type of area. (Note that the costs have been rounded.)

Table 11: Estimated Outside Plant Costs (Directional Boring Cost Estimate)

Area	Distribution Plant Mileage	Total Cost	Passings	Cost per Passing	Cost Per Plant Mile
Entire City	1,600	$703,292,000	374,000	$1,880	$440,000
High Density	20	$10,875,000	26,000	$420	$544,000
Medium Density	400	$200,439,000	140,000	$1,430	$501,000
Low Density	1,180	$491,978,000	208,000	$2,370	$417,000

[44] This is the High-Cost Scenario. The passing count includes individual single-unit buildings and units in multi-dwelling and multi-business buildings as single passings. In larger MDUs, the cost estimate assumes that existing wiring will be used to serve the units. We assume that each unit will cost $500 per unit in large MDUs.

Table 12: Estimated Outside Plant Costs (Sidewalk Restoration Cost Estimate)

Area	Distribution Plant Mileage	Total Cost	Passings	Cost per Passing	Cost Per Plant Mile
Entire City	1600.0	$762,858,000	373,480	$2,040	$480,000
High Density	20.0	$11,686,000	25,960	$450	$644,000
Medium Density	400.0	$211,365,000	139,940	$1,510	$531,000
Low Density	1,180.0	$539,807,000	207,580	$2,600	$459,000

Costs for aerial and underground placement were estimated using available unit cost data for materials and estimated labor costs for placing, pulling, and boring fiber based on construction in comparable markets.

Barring unknown economies of scale and inflation rates, as well as any sort of phenomenon restricting material availability and costs, material costs were generally straightforward.

We estimated labor costs associated with the construction of fiber based on similar FTTP construction projects, information from service providers in the City, and the costs the City has paid for other fiber construction.

Aerial construction entails the attachment of fiber infrastructure to existing utility poles, which could offer significant savings compared to all-underground construction, but increases uncertainty around cost and timeline. The utility pole owners and other attached providers can impose costs and delays related to pole remediation and "make-ready" construction that can make aerial construction cost-prohibitive in comparison to underground construction.

While generally allowing for greater control over timelines and more predictable costs, underground construction is subject to uncertainty related to congestion of utilities in the public rights-of-way and the prevalence of subsurface hard rock—neither of which can be fully mitigated without physical excavation and/or testing. While anomalies and unique challenges will arise regardless of the design or construction methodology, the large scale of this project is likely to provide ample opportunity for variations in construction difficulty to yield relatively predictable results on average.

We assume underground construction will consist primarily of horizontal, directional boring to minimize right-of-way impact and to provide greater flexibility to navigate around other utilities. The design model assumes a single two-inch, High-Density Polyethylene (HDPE) flexible conduit over underground distribution paths, and dual two-inch conduits over underground backbone paths to provide scalability for future network growth.

2.4.4 Central Network Electronics Costs

Central network electronics will cost an estimated $112 million, or $300 per passing, based on an assumed take rate of 100 percent.[45] (These costs may be phased in as subscribers are added to the network.) The central network electronics consist of the electronics to connect subscribers to the FTTP network at the core, hubs, and cabinets. Table 13 below lists the estimated costs for each segment.

Table 13: Estimated Central Network Electronics Costs

Network Segment	Passings	Cost per Passing	Subtotal
Core and Distribution Electronics	373,000	$100	$37 million
FTTP Access Cabinet Electronics	373,000	$200	$75 million
Central Network Electronics Total	**373,000**	**$300**	**$112 million**

2.4.4.1 Core Electronics

The core electronics connect the hub sites and connect the network to the internet. Core electronics consist of high-performance routers, which handle all the routing both on the FTTP network and to the internet. The core routers should have modular chassis to provide high availability in terms of redundant components and the ability to "hot swap"[46] line cards and modular in the event of an outage. Modular routers also provide the ability to expand the routers as demand for additional bandwidth increases.

The cost estimate design envisions redundant rings between the core sites running networking protocols such as hot standby routing protocol (HSRP) to ensure redundancy in the event of a core failure. Additional rings can be added as bandwidth on the network increases. The core sites would also tie to both hubs using 10 Gbps links. The links to the hubs can also be increased with additional 10 Gbps and 40 Gbps line cards and optics as demand grows on the network. The core networks will also have 40 Gbps to internet service providers that connect the FTTP network to the internet.

The cost of the core routing equipment for the two core sites is $8 million. These costs do not include the service provider's Operational Support Systems (OSS) such as provisioning platforms,

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[45] The take rate affects the electronics and drop costs, but also may affect other parts of the network, as the City may make different design choices based on the expected take rate. In CTC's financial analysis, we will examine how the feasibility of the project depends on a range of take rates.

[46] A "hot swappable" line card can be removed and reinserted without the entire device being powered down or rebooted. The control cards in the router should maintain all configurations and push them to a replaced line card without the need for reconfirmation.

fault and performance management systems, remote access, and other operational support systems for FTTP operations. Service providers and/or their content providers may already have these systems in place.

2.4.4.2 Distribution Electronics

The distribution network electronics at the two hub sites aggregate the traffic from the FDCs and send it to the core sites to access the internet. The core sites consist of high-performance aggregation switches, which consolidate the traffic from the many access electronics and send it to the core for route processing. The distribution switches typically are large modular switch chassis that can accommodate many line cards for aggregation. The switches should also be modular to provide redundancy in the same manner as the core switches.

This cost estimate assumes that the aggregation switches connect to the access network electronics with 10 Gbps links to each distribution switch. The aggregation switches would then connect to the core switches over single or multiple 10 Gbps links as needed to meet the demand of the FTTP users in each service area.

The cost of the distribution switching equipment for distribution hubs is $29 million. These costs do not include any of the service provider's OSS or other management equipment.

2.4.4.3 Access Cabinet Electronics

The access network electronics at the FDCs connect the subscribers' CPEs to the FTTP network. We recommend deploying access network electronics that can support both GPON and Active Ethernet subscribers to provide flexibility within the FDC service area. We also recommend deploying modular access network electronics for reliability and the ability to add line cards as more subscribers join in the service area. Modularity also helps reduce initial capital costs while the network is under construction or during the roll out of the network.

The cost of the access network electronics for the network is $74 million. These costs include optical splitters at the FDCs and are based on a take rate of 100 percent under the utility delivery model.

2.4.5 Subscriber Electronics and Service Drop Installation Costs (Per-Subscriber Costs)

Each activated subscriber would also require a fiber drop installation and subscriber electronics, which would cost roughly $2,600 to $2,800 per subscriber, or $970 million to $1.0 billion total.

These costs are summarized in Table 14.

Table 14: Per-Subscriber Activation Cost Estimates

Construction and Electronics Required to Activate a Subscriber	Estimated Average Cost
Drop Installation and Materials	$1,800 to $2,000
Subscriber Electronics (ONT and OLT)	500
Electronics Installation	200
Installation Materials	100
Total	**$2,600 to $2,800**

The numbers provided above are averages and will vary depending on the type of premises and the internal wiring available at each premises.

2.4.5.1 Customer Premises Equipment and Related Subscriber Electronics

The per-subscriber expenses for electronics are the cost of the optical network terminal (ONT) at the premises, a portion of the optical line termination (OLT) costs at the hub, the labor to install and configure the electronics, and the incidental materials needed to perform the installation.

The ONT, also known as customer premises equipment (CPE), is the subscriber's interface to the FTTP network. For this cost estimate, we selected CPEs that provide only Ethernet data services (however, there are a wide variety of CPEs offering other data, voice, and video services). Assuming a 100 percent take rate under the utility delivery model, we estimated the CPE for customers will be $290 million. For large MDUs we assume the use of internal wiring. The cost estimate assumes the use of an Ethernet switch or a G.Fast or G.hn network access multiplexer and network terminal.

2.4.5.2 Drop Installation

The drop installation cost is the biggest variable in the total cost of adding a subscriber. A short aerial drop can cost as little as $250 to install, whereas a long underground drop installation in a congested underground area like San Francisco can cost upward of $5,000. In this model, we estimate an average of $1,800 to $2,000 per drop installation, for a total of $680 million to $740 million.

To estimate the cost of the drops, we determined the average drop length for each subscriber. The average drop length is calculated using a variety of variable and assumptions including average house set-back, average home frontage, and nearest tap placement. Less dense areas have longer drops however they tend to have more aerial construction which is less expensive.[47]

[47] The FTTP fiber distribution plant is approximately half aerial and half underground, therefore half of the drops will be aerial and half the drops will be underground. Table 9 provides the breakdown of aerial plant between density areas.

We assumed a cost of approximately $400 for the installation of an aerial drop or pulling a drop through existing conduit. In underground areas, we assumed a cost of $50 to $65 per foot for underground conduit placement. MDUs larger than 20 units receive a single lateral to serve the entire building. The following tables summarize the drop costs (and have been rounded).

Table 15: Estimated Drop and Lateral Costs (Directional Boring Estimate)

Area	Total Drop Costs	Passings	Total Drop Footages	Average Drop Length	Drop Cost Per Passing
Entire City	$680,000,000	373,000	23,000,000	133	$1,800
High Density	$11,000,000	26,000	300,000	98	$700
Medium Density	$200,000,000	140,000	8,800,000	124	$1,700
Low Density	$490,000,000	207,000	13,900,000	142	$2,100

Table 16: Estimated Drop and Lateral Costs (Sidewalk Replacement Estimate)

Area	Total Drop Costs	Passings	Total Drop Footages	Average Drop Length	Drop Cost Per Passing
Entire City	$741,000,000	373,000	23,000,000	125	$2,000
High Density	$19,000,000	26,000	300,000	98	$700
Medium Density	$260,000,000	140,000	8,800,000	124	$1,900
Low Density	$462,000,000	207,000	13,900,000	142	$2,200

The cost of underground construction drives the average drop. For example, an installation requiring 30 feet of underground construction costs $1,900 ($400 for the drop at $1,500 for conduit installation at $50 per foot). Whereas, in a suburban community where a drop could be plowed through a grassy yard the cost would only be $700 assuming a conduit installation cost of $10 per foot.

3 The Purely Public Broadband Option Involves High Risk

In evaluating the options before the City, the Project Team considered a purely public model, in which the City would build, own, and operate an FTTP network itself. This is a high-risk and high-reward proposition, with a respectable track record in communities across the country. In our observation, however, this is a difficult model to replicate, particularly for a city that does not own its electric utility or one that does not have the internal expertise to build and operate an internet enterprise. Aggressive anti-municipal efforts by incumbent phone and cable companies make this model even more risky. The purely public model has never been undertaken by a city of the size or profile of San Francisco.

And the economics of the model are likely to be challenging in San Francisco. Assuming the lower cost estimate developed by the engineers, the City would require financing of almost $1.29 billion in bonds and a $20 million loan. To break even, the City would require a 47 percent take rate in both the business and residential markets. If implementation costs approach the high cost estimate, developing a project that is financially feasible becomes even more challenging. The total bonding in the first four years increases to roughly $1.43 billion, plus the initial loan of $20 million. The take rate required to break even increases to 53 percent.

3.1 Background

Over the past 25 years, about 100 local communities have built hybrid fiber-coaxial (HFC) networks (the architecture used by cable companies) or FTTP networks to comprehensively serve residential and business markets. In almost every case, these networks have been deployed in small to mid-size towns in largely rural areas. Some, but not all, of these towns already had cable modem service, but many of them were unserved or close to unserved by broadband service.

3.1.1 Track Record of Public Broadband Efforts in FTTP

The economics of FTTP are extremely challenging given the very high capital costs and the modest revenues possible, particularly in light of competition from lesser broadband technologies. Unlike other public utilities such as water and sewer, city communications networks do not operate in a monopoly environment, and a number of competitor technologies, however inferior, do exist. These include far-lower-bandwidth options such as DSL, cable modem service, and wireless service. (In contrast, some of the municipal FTTP networks were built a decade or more ago at a time when there may not have been much or any competition in those rural towns.) These alternative technologies do not offer the same future-proof scalability and speeds as fiber, but can certainly offer robust competition with respect to price and other factors.

Tremendous successes have been achieved by public FTTP networks such in Lafayette, Louisiana; Chattanooga, Tennessee; and Wilson, North Carolina—all of which are municipal electric utilities that achieved substantial efficiencies.[48]

The most dramatic successes of these networks are in the benefits that do not necessarily show up on financial statements—such as enhanced productivity, innovation, education, health care, company recruitment, and related benefits that are among the reasons for the communications investment in the first place.

A modest subset of the municipal FTTP and HFC networks have struggled financially for a range of reasons, including the challenges created by incumbent opposition to municipal networks, which in some states has restricted municipal options (for example, in Utah, municipalities are statutorily prohibited from offering retail services—a law that was passed at the behest of the incumbent providers, and that has created significant economic challenges for municipal networks) but also ongoing litigation, anti-municipal PR campaigns, and related efforts to delay, obstruct, and increase the costs of municipal efforts.

The significant challenging economics of competitive broadband have also played a factor in creating real financial challenges for a subset of the municipal networks. In some communities, some of the functions required to operate a competitive internet, cable, and phone enterprise have simply proven challenging for public sector entities—in particular such critical elements as superior customer service in a competitive market is challenging even for private companies, and has proven so for some public entities as well.

3.1.2 Track Record of Public Broadband in California

A handful of municipal networks that have stumbled have emerged and been widely publicized by anti-municipal incumbents and their allies. In California, there exist a number of very successful municipal efforts, particularly those with more modest or incremental goals. For example, the city of Santa Monica built fiber optics beginning in the late 1990s to connect government buildings and has been successful in expanding its network and offering services in the commercial market, though it has not to date entered the residential market. Similarly, the city of Palo Alto's municipal electric utility has seen tremendous success in leasing to the private sector dark fiber strands on its backbone network.

[48] Christopher Mitchell, "Broadband At the Speed of Light: How Three Communities Built Next-Generation Networks," Institute for Local Self-Reliance, April 2012, http://www.ilsr.org/wp-content/uploads/2012/04/muni-bb-speed-light.pdf (accessed March 2017). *See also*: Julie Kendrick, "The Broadband Challenge," *The Line,* July 18, 2012, http://www.thelinemedia.com/features/broadband071812.aspx (accessed March 2017).

Ubiquitous broadband to the home has proven more challenging. The city of Alameda, for example, built a hybrid fiber-coaxial cable and internet network that it later sold at a substantial loss to Comcast following a number of years of challenging financial outcomes.

3.1.3 Advantages of Having a Public Electric Utility

The majority of the public networks that have been deployed were deployed by municipal electric utilities. This correlation is not surprising for a number of reasons. First, communities in which the private sector did not have a business case for electrification are where local governments chose to build public power. Not surprisingly, those same communities did not see adequate private sector investment in broadband, either, and thus chose, in both cases, to invest for the benefit of the broader community.

Second, the challenge of undertaking a public-facing communications project is reduced for a municipal electric utility relative to a local government that is not already a power provider. A range of elements of a communications network overlap those of a power network, including the poles on which the infrastructure is built, the facilities in which network hubs are located, the skills and equipment of field staff, and even, in some cases, the billing, operating, and customer service systems that support the service offerings. A minority of the municipal, public-facing networks were built by localities that were not power utilities.

3.2 Benefits

While it comes at considerable cost, municipal broadband offers demonstrable and important benefits, including municipal decision-making and control with regard to critical factors such as insuring that the network is made universally accessible to all members of the community rather than building only to areas with a higher return on investment.

Municipal ownership also delivers considerable flexibility and opportunity to expand, change business models, and otherwise innovate as necessary to meet the needs of the community.

An additional and critical area of benefit is in regard to pricing and the affordability that is created by a competitive dynamic. The municipal FTTP and HFC networks to date have tended to be in markets where the likelihood of a third private competitor emerging was slim to nonexistent. In fact, some of these networks have developed in markets where only one or no broadband competitors existed. As a result, these municipal networks have almost universally delivered a level of competition that was inconceivable otherwise.

3.3 Challenges

At the same time, municipal networks present considerable challenges. In addition to the financial risk entailed in building and operating a venture that competes with private sector service offerings in some cases, a number of other challenges present themselves. Municipal networks are generally only possible when a city is in a position to issue bonds to raise capital to build the network. In many cases, even cities with outstanding credit ratings are unable to bond to support a communications network because of other critical priorities, such as shoring up pension funds, building schools and public safety facilities, and the many other functions of government for which bonding capacity must be reserved. And bonding capacity is limited in any city, no matter how good its credit rating or how prosperous its economy.

Competing needs for capital are thus a considerable challenge around municipal efforts. At the same time, additional challenges can be created in multiple functional areas associated with construction, operations, and maintenance of a communications enterprise. The challenges can range from the considerable difficulty of hiring network engineers, particularly in the Bay Area of California where network engineers are in such demand and command very high private sector salaries that are difficult for the public sector to match.

3.4 Financial Analysis

To fully understand the potential viability of the purely public model for this initiative, the Project Team developed a full financial model and analysis of the economics of the traditional municipal ownership and operations model. (See Appendix J.)

Under this model, and assuming the lower cost estimate developed by the engineers, the City would require financing of almost $1.29 billion in bonds and a $20 million loan. To break even, the City would need almost half of all residences and businesses to buy services—a very robust take rate.

The base case analysis assumes that the City offers three data services:

- 1 Gbps residential service at $80 per month
- 1 Gbps small commercial service at $90 per month
- 1 Gbps medium commercial service (with service-level agreements) at $240 per month[49]

These service prices are above those of Google Fiber in other markets ($70 for 1 Gbps) but are lower than some other providers' pricing. For example, Comcast's recently announced residential 1 Gbps service in San Francisco is priced at $160 per month, with introductory promotional pricing at $70 per month, plus an equipment rental fee of $10 per month.

The model assumes that subscribership for data services will ramp up over years one through four, and then remain steady. The model assumes that subscribership for voice and video services

[49] Medium commercial service receives a lower oversubscription rate, that is, less customers sharing the connection, decreasing the instances of network congestion reducing overall speeds.

will ramp up over the same period, but then decline as adoption of over-the-top (OTT) alternatives increases.

If the take rate assumed in this base case analysis were to drop, or if the City were unable to maintain service prices at the levels assumed in our analysis, the enterprise would accumulate significant deficits over time.

As an example, our sensitivity analysis indicates that if the take rate were to drop by 10 percentage points, the enterprise would quickly turn from an unrestricted cash balance of about $406,000 in year one to a negative cash balance. By year five, the unrestricted cash balance deficit would be over $61.9 million, growing to a deficit of more than $324 million by year 20.

We also found that if competitive pressures were to force the City to reduce the residential internet service fee by $5 per month from the levels assumed in the base case, the enterprise would not be financially feasible. By year 10, the unrestricted cash balance deficit would be more than $58.2 million, growing to a deficit of just under $126 million by the end of year 20.

4 The Purely Private Option Will Not Meet the City's Goals of Open, Ubiquitous Fiber to All Homes and Businesses

With respect to the key goals identified for this initiative—open access and direct fiber connectivity to every home and business in San Francisco—private deployment alone is unlikely to suffice. Though there are emerging patterns of new deployment by competitors and upgrades by incumbents, none of the providers in San Francisco offers an open access network and none of them plans to build fiber on a ubiquitous basis.

There exists little agreement about the degree to which private capital is emerging to expand broadband competition and improve broadband speeds. Nationally, while the incumbent communications companies claim to be investing extensively in upgraded and new broadband facilities, robust new fiber investment tends to be concentrated in markets that already feature strong competition (such as those where Google Fiber deployed extensive residential fiber) or more incremental in nature (for example, incremental expansion of the cable industry's fiber backbone to support new cable modem technologies, or incremental expansion of the phone company's fiber footprint to reach large business customers).

San Francisco's residents and businesses have a relatively broad range of services available, as compared to other urban areas. However, as compared to FTTP areas (such as Verizon FiOS and Google Fiber cities and the FTTP networks in major cities in Asia), San Francisco is among the American cities without citywide residential fiber.

In San Francisco, none of the City's incumbent wired providers (AT&T, Wave, and Comcast) has indicated any plans to deploy fiber on a ubiquitous basis, although new competition is emerging in smaller, select areas thanks to new investment by companies like Sonic, Monkeybrains, and Webpass.

Verizon offers FiOS in parts of Southern California but has not indicated any plans of extending the service to San Francisco. Google Fiber's expansion appears halted, at least for now, though Google Access' Webpass unit is expanding in the multi-dwelling unit market downtown.

Comcast has upgraded its entire San Francisco service footprint[50] to the next generation of cable modem technology, which enables speeds of up to 1 Gbps in the downstream direction under optimal conditions. AT&T is also upgrading its infrastructure to fiber in many parts of San Francisco, but it's unlikely that the upgrade will be citywide or ubiquitous. AT&T's upgrades in many cities thus far have been incremental and concentrated in select neighborhoods,

[50] Comcast informed CTC and City staff in a September 2017 meeting that its network reaches 98.9 percent of residences and 56 percent of businesses in San Francisco.

sometimes based on where AT&T already has fiber and can cost-effectively extend it, or on areas where AT&T has reason to build fiber to serve large enterprise customers.

In summary, while Comcast's upgrade has improved speeds throughout the City, and while the other companies are all incrementally growing or upgrading their existing facilities, the private sector is not currently poised to deliver ubiquitous service or ubiquitous competition throughout San Francisco. There does exist new investment, which may increase with time, but the results will be uneven and inconsistent, with some but not all areas seeing substantially improved services.

4.1 AT&T

AT&T is the primary incumbent local exchange carrier in San Francisco and much of California, where it offers DSL and other copper-line services to most of the City and provides fiber services such as Metro Ethernet to businesses. Because the cost of the fiber services is substantially higher than the DSL services, small and medium-sized businesses may have difficulty affording these enhanced services.

DSL represents a relatively low-bandwidth form of broadband—a network of roads, not superhighways. DSL runs on telephone network copper wires, which simply cannot handle the same capacity as fiber or even as Comcast's hybrid fiber-coaxial (HFC) networks. As capacity requirements increase, DSL is likely to fall further behind cable.[51] Even with newer DSL versions, such as the VDSL fiber-to-the-cabinet service providing download speeds of approximately 50 Mbps,20 its speed is significantly lower that what is available over cable or fiber. From a technical standpoint, DSL is a short-term solution in a market where bandwidth needs are growing exponentially and high, symmetrical capacity is increasingly needed for small businesses and for popular applications like video-downloads, video-gaming, and video-conferencing. Aging copper plant is not capable of meeting these growing needs in the long run.

In a very positive development, AT&T has recently started upgrading some areas in a few dozen cities throughout the country to FTTP[52] and we have observed AT&T upgrading infrastructure in some parts of San Francisco. It's not clear how extensive the fiber upgrade in San Francisco will be, and experience in other cities suggests it is unlikely to be ubiquitous.

[51] The limitations of DSL are illustrated by Verizon's investment, over the past decade or so, to supplement its old copper phone networks with new FTTP networks in limited metropolitan areas within its existing footprint, and by AT&T's limited but effective expansion of fiber in some markets where it faces competition.

[52] "100% Fiber Network Powered by AT&T Fiber Expands in 17 Metros – See if It's Near You," AT&T, March 23, 2017, http://about.att.com/newsroom/att_fiber_expands_to_17_metro_areas.html; http://www.theverge.com/2017/3/24/15056428/at-t-continues-to-expand-its-fiber-internet-service (accessed June 2017).

4.2 Comcast

In San Francisco, Comcast operates a hybrid fiber-coaxial system that ably competes against other offerings in the existing marketplace. Comcast has also indicated that it will upgrade its network in San Francisco to the next generation of cable modem technology, known as DOCSIS 3.1, within the next year or two.[53] That upgrade, if it is also supported by additional fiber construction, will enable Comcast to offer ("up to") gigabit speeds in the downstream direction to many San Francisco consumers. Pricing for this product in other markets has thus far exceeded $150.

Comcast's network, however, is limited by its lack of fiber—even with advanced electronics and software, its system cannot keep pace with the potential speeds of fully-fiber networks such as those operated by Verizon, Google Fiber and, in limited areas, AT&T and CenturyLink. Cable systems are bound by the inherent limitations of the coaxial cable that runs from their nodes into the home. An additional limitation arises from the shared nature of cable modem service—bandwidth within a neighborhood is shared rather than dedicated. As a result, promised speeds of "up to" 1 Gbps downstream (and considerably less upstream) may be significantly decreased by one's neighbors' simultaneous use of their cable modems.

Importantly, the DOCSIS 3.1 upgrade provides the potential for higher speeds to nearly all San Francisco residents, because the upgrade covers the entire service area, not on an incremental or partial basis (for technical reasons, an electronics upgrade such as DOCIS 3.1 is done on a system-wide basis).

In contrast, however, the DOCSIS 3.1 technology will not be available for those in small business areas that are outside Comcast's existing footprint. Because the traditional footprint of cable companies was residential only, for purposes of selling one-way cable video products, cable networks frequently do not reach into business areas where there exists insufficient for new infrastructure investment. As a result, some business areas do not have the benefit of Comcast's networks and extension of the infrastructure to those businesses can be prohibitively expensive.

Comcast also offers "Gigabit Pro," its FTTP symmetrical 2 Gbps residential service, in limited parts of San Francisco. Gigabit Pro is only available to customers within a quarter to a third of a mile of Comcast's existing fiber backbone—and the service require extension of that fiber the customer's

[53] Jon Brodkin, "Comcast's gigabit cable will be in 15 cities by early 2017," *ArsTechnica*, November 2, 2016, https://arstechnica.com/information-technology/2016/11/comcasts-gigabit-cable-will-be-in-15-cities-by-early-2017/ (accessed June 2017).

premises, which can take many weeks. As of late 2016, Comcast was charging approximately $1,000 for installation and service activation. Monthly service fees are approximately $300.[54]

4.3 Etheric Networks

Etheric Networks is a privately owned, fixed-wireless ISP, based in Redwood City, with coverage areas spanning from Salinas to Berkeley. Since 2003, the company has deployed licensed microwave antennas to connect customers to its fiber backbone.[55] The company also provides direct fiber connections for businesses in select locations.

Its residential service comes with a $400 to $440 startup fee, covering the cost of new antennas and their installation. Then service costs $85 to $350 per month for guaranteed minimum, symmetrical speeds ranging from 1 Mbps to 25 Mbps. They also have more expensive small business/home office service with lower latency and greater burst potential available in some areas. This SOHO service costs $160 to $700 per month with guaranteed speeds between 3 Mbps and 25 Mbps. Etheric's business service levels range from $200 to $1,500 per month, with guaranteed speeds ranging from 2 Mbps to 100 Mbps.[56]

Etheric reports that it continues to deploy higher-speed wireless technologies as they become available, but the company has shared no plans to further expand its fiber backbone at this time.

4.4 Monkeybrains

Monkeybrains is a San Francisco-based ISP that started offering dial-up service in 1998. It focuses exclusively on serving the San Francisco area, but does not offer service in much of the western region of the City. Over the years, it has continued to improve its service offerings as better technologies have become available to connect customers to its core fiber network. In 2009, it began using microwave technology to connect end customers to its core fiber network. It now has a network of more than 1,000 network access points across the City, which send signals along line-of-sight connections to antennas on customer premises.

Monkeybrains' standard residential service costs $35 a month, after a $250 antenna setup fee. In 2015, it used a crowdfunding campaign to negotiate a bulk buying discount on millimeter wave radios. Through the crowdfunding campaign, customers could cover the cost of the $2,500 antenna, and as a reward, Monkeybrains promised to deliver 300 to 500 Mbps to their home or

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[54] Jon Brodkin, "Comcast's gigabit cable will be in 15 cities by early 2017," *ArsTechnica*, November 2, 2016, https://arstechnica.com/information-technology/2016/11/comcasts-gigabit-cable-will-be-in-15-cities-by-early-2017/ (accessed June 2017).

[55] Robert Mullins, "Etheric Bootstraps to build wireless broadband network," *Silicon Valley Business Journal,* November 30, 2003, http://www.bizjournals.com/sanjose/stories/2003/12/01/story5.html/ (accessed June 2017).

[56] Etheric Networks, https://ethericnetworks.com/ (accessed June 2017).

office at the same monthly price of $35. Through the campaign, 273 backers helped the company raised $420,501, enough to purchase almost twice as many antennas as planned. The company used the extra funds from the project to deploy additional antennas on the roofs of schools, homeless shelters, and cultural centers across the City.[57]

While Monkeybrains' standard service remains 20 Mbps/10 Mbps, it also offers business packages with symmetrical speeds ranging from 20 Mbps to 1+ Gbps.[58] Their service levels will likely improve as wireless technologies get better and more affordable, but the company leadership acknowledges that at some point they will have to invest more heavily into fiber. The founders have reportedly stated that they have no plans to invest in last-mile fiber links until there is "'some sort of relaxation in the right-of-way access [of fiber].'"[59]

FCC Form 477 data are not available for Monkeybrains, but our understanding of the Monkeybrains service footprint is that it is limited to certain areas of single-family homes in San Francisco.

4.5 Wave

Wave is a Kirkland, Washington, based ISP with a network that includes metropolitan areas on the West Coast from the Bay Area to Seattle. The privately-held company was recapitalized for more than $1 billion in November 2012,[60] and raised $130 million in 2015[61] and another $125 million in 2016.[62] It is using these funds to expand its fiber and coaxial footprint through new construction and acquisitions.

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[57] Rick Paulus, "Can an Indie ISP beat Comcast?" *Popular Mechanics,* March 14, 2016, http://www.popularmechanics.com/technology/infrastructure/a19741/can-an-indie-isp-beat-comcast/ (accessed June 2017).

[58] Monkeybrains.net, https://www.monkeybrains.net/business.php (accessed June 2017).

[59] Rick Paulus, "Can an Indie ISP beat Comcast?" *Popular Mechanics,* March 14, 2016, http://www.popularmechanics.com/technology/infrastructure/a19741/can-an-indie-isp-beat-comcast/ (accessed June 2017).

[60] "WaveDivision Holdings Raises $1.052 Billion, Plans to accelerate Expansion of West Coast Broadband/Fiber Optic Network," Press Release, Waller Capital, November 15, 2012, http://www.wallercapital.com/wavedivision-holdings-raises-1-052-billion-plans-to-accelerate-expansion-of-west-coast-broadbandfiber-optic-network/ (accessed June 2017).

[61] Mike Farrell, "Wave Raises $130M for Fiber Build," *MultiChannel News*, May 21, 2015, http://www.multichannel.com/news/broadband/wave-raises-130m-fiber-build/390795 (accessed June 2017).

[62] "Wave Raises $125 Million to Continue Accelerated Fiber Network Construction and Commercial Broadband Services Expansion," Press Release, Wave, September 14, 2016, http://residential.wavebroadband.com/wave-raises-125-million-to-continue-accelerated-fiber-network-construction-and-commercial-broadband-services-expansion/ (accessed June 2017).

Wave began offering gigabit residential internet service in San Francisco in June, 2015. It has focused its fiber efforts on large MDUs, and it does not share the location of its existing fiber plant. Where available, the service costs $80 per month.

Consumers who do not live in a building with Wave-G gigabit service may still be able to receive up to 110 Mbps service over Wave's hybrid fiber coaxial (HFC) network.[63] The company also offers business speeds up to 1 Gbps, but service levels above 250 Mbps are only available in select locations, or with added new construction fees.[64]

While it is unclear how much new fiber construction Wave has planned for the San Francisco area, the company recently put out a job listing for a fiber construction lead in San Francisco.[65] The company will likely continue to expand fiber to MDUs, but has not indicated any intention to expand its FTTP service to single family homes.

The following map (Figure 10) illustrates the reach of Wave's services, and is based on self-reported data provided by Wave to the FCC.[66]

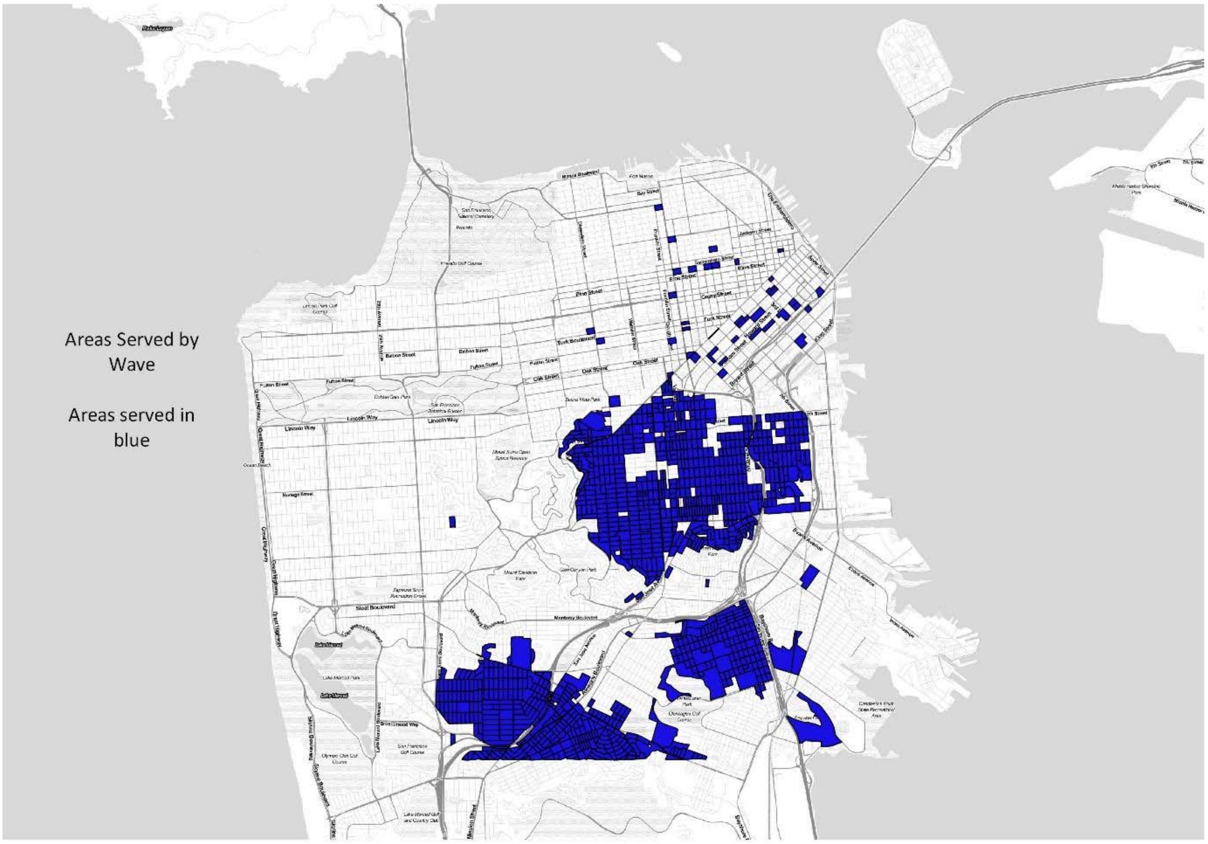
[63] "San Francisco, CA Cable TV, Internet, and Phone Service," Wave, http://residential.wavebroadband.com/resources/cities/san-francisco-cable-internet-phone.php (accessed June 2017).

[64] "High Speed Internet, Wave, http://residential.wavebroadband.com/internet/ (accessed June 2017).

[65] "Fiber Construction Lead: Wave Broadband, San Francisco Bay Area," Job Listing, LinkedIn, https://www.linkedin.com/jobs/view/249977325 (accessed June 2017).

[66] The map is based on FCC Form 477 data as of June 30, 2016, https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477 (accessed June 2017).

Figure 10: Wave Service in San Francisco



4.6 Webpass

Webpass is a wireless ISP, founded in San Francisco in 2003. The company uses millimeter wave antennas to offer high-speed service to customers in MDUs. When Alphabet's access division, Google Access, purchased the company in June, 2016, Webpass had infrastructure to serve some residential MDUs and office buildings in San Francisco, Oakland, San Diego, Miami, Chicago, and Boston.[67]

[67] "A Great Day," *Webpass Blog,* October 3, 2016, https://webpass.net/blog/a-great-day (accessed June 2017).

Since the acquisition, Google Access has scaled back its FTTP efforts[68] and appears to be moving forward with Webpass' wireless strategy.[69] Webpass has launched new service in Denver, and appears to be preparing to launch in Seattle.[70]

Webpass offers its customers speeds ranging from 100 Mbps to 1 Gbps for $60 per month.[71] Webpass continues to expand its services to new buildings in the markets it serves. In order to be eligible for Webpass service, a building must have at least 10 units and be wired with Ethernet cabling.[72] It appears unlikely that Webpass will provide service to single family homes in the near future due to the high cost of the millimeter wave antennas that the company relies on for its last-mile connections.[73]

FCC Form 477 data are not available for Webpass, but our understanding of the Webpass service footprint is that it is concentrated in MDUs in the downtown area of San Francisco.

4.7 Sonic

Sonic is a Santa Rosa-based ISP that has been in business since 1994. Historically, Sonic offered DSL service over AT&T's copper phone lines, but the company has steadily expanded its network across the Bay Area, and began offering fiber-based service to residential customers in limited areas in 2011, with fiber-based business service soon to follow.[74] After building smaller FTTP projects in North and East Bay, Sonic announced in February 2016 the provision of Gigabit fiber

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[68] Jon Brodkin, "Google Fiber division cuts staff by 9%, 'pauses' fiber plans in 11 cities," *ArsTechnica*, October 25, 2016, https://arstechnica.com/information-technology/2016/10/google-fiber-laying-off-9-of-staff-will-pause-plans-for-10-cities/ (accessed June 2017).

[69] Jack Clark, "Google Plots Cheaper Wireless Future to Expand Fiber Project," *Bloomberg Technology*, July 28, 2016, https://www.bloomberg.com/news/articles/2016-07-28/google-plots-cheaper-wireless-future-to-expand-fiber-project (accessed June 2017).

[70] Jon Brodkin, "Google Fiber makes expansion plans for $60 wireless gigabit service," *ArsTechnica*, February 22, 2017, https://arstechnica.com/information-technology/2017/02/google-fiber-makes-expansion-plans-for-60-wireless-gigabit-service/ (accessed June 2017).

[71] Jon Brodkin, "Google Fiber makes expansion plans for $60 wireless gigabit service," *ArsTechnica*, February 22, 2017, https://arstechnica.com/information-technology/2017/02/google-fiber-makes-expansion-plans-for-60-wireless-gigabit-service/ (accessed June 2017).

[72] "More Places To Grab Gigabit, With Webpass," Blog Posting, Webpass, January 30, 2017, https://webpass.net/blog/more-places-to-grab-gigabit-with-webpass (accessed June 2017).

[73] Bruce Brown, "Google Fiber Isn't Just Fiber Anymore—Now It Offers Wireless Service, Too," *Digital Trends*, October 5, 2016, http://www.digitaltrends.com/web/google-fiber-webpass-hybrid-internet-fiber-wireless/ (accessed June 2017).

[74] Martin Espinoza, "Sonic increases investment in fiber networks," *The Press Democrat*, January 18, 2015, http://www.pressdemocrat.com/news/3310907-181/sonic-increases-investment-in-fiber?artslide=0 (accessed June 2017).

service available in parts of the Sunset and Richmond neighborhoods.[75] Over the past year, Sonic has continued to build fiber infrastructure in San Francisco neighborhoods where construction costs are lowest (generally, areas with overhead utilities, which tend to offer lower costs than underground construction). Sonic's leadership suggested in recent meetings with the City that the company will expand its FTTP footprint to additional areas of San Francisco with aerial utilities over the next year or so. Even in aerial areas, Sonic's construction is not uniform and tends to skip areas where costs and complexity are higher. We thus do not expect Sonic's fiber construction to be ubiquitous, even in the neighborhoods where it plans to build.

Where available, Sonic's gigabit service is $40 per month ($58 including taxes and fees),[76] and includes a free phone line.

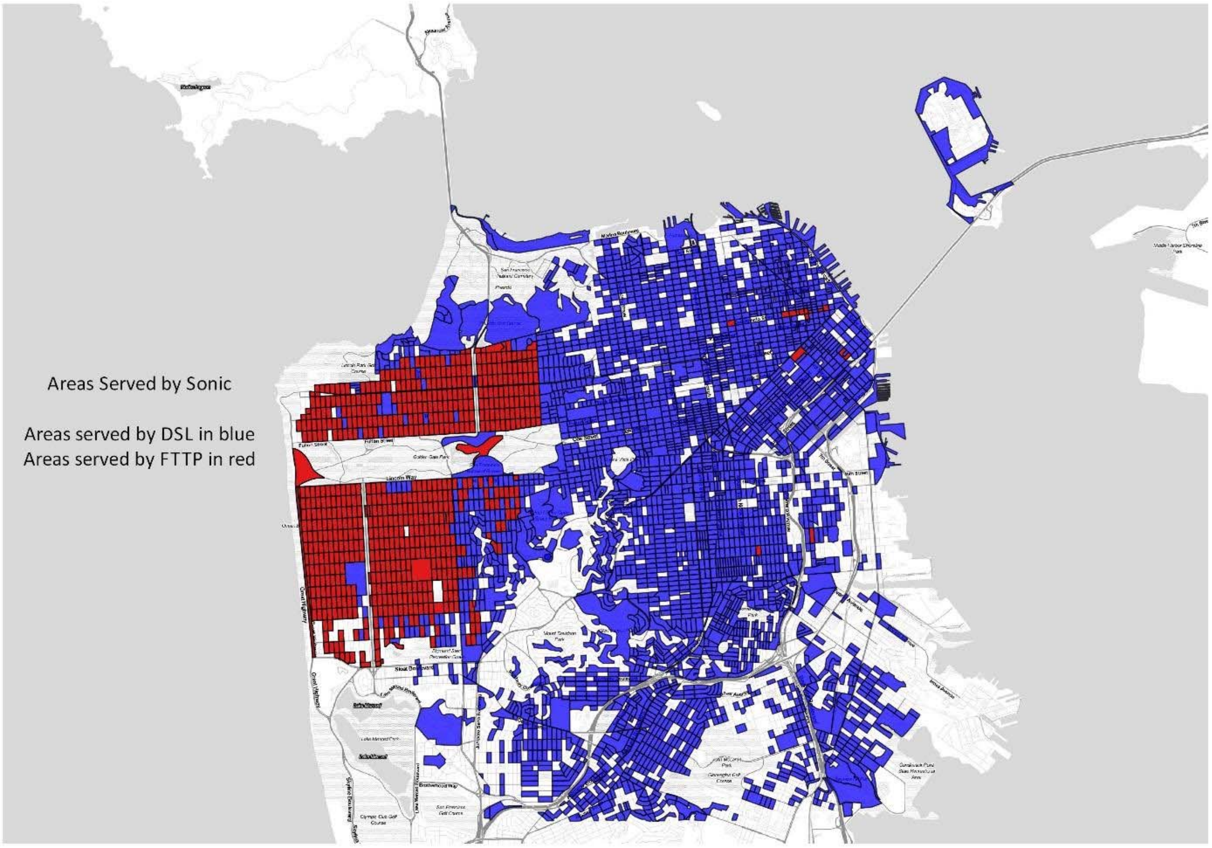
The following map illustrates the reach of Sonic's services, and is based on self-reported data provided by Sonic to the FCC.[77]

[75] Dane Jasper, "Sonic Fusion Gigabit Fiber Now Available in San Francisco," Blog Posting, Sonic, February 25, 2016, https://corp.sonic.net/ceo/2016/02/25/sonic-fusion-gigabit-fiber-now-available-in-san-francisco/ (accessed June 2017).

[76] Bernie Arnason, "Sonic Brings Disruptive Pricing for Gigabit Services Ahead of Google Fiber," *Telecompetitor*, February 26, 2016, http://www.telecompetitor.com/sonic-brings-disruptive-pricing-for-gigabit-services-ahead-of-google-fiber/ (accessed June 2017).

[77] The map is based on FCC Form 477 data as of June 30, 2016, https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477 (accessed June 2017).

Figure 11: Sonic Service in San Francisco



4.8 Factors That Can Impact Private Deployment Patterns

Every company obviously makes unique decisions about deployment based on its technology choices, available capital, business plan, and return on investment requirements. In an environment where the private sector has complete control over that dynamic, there exists a wide range of factors that will determine deployment patterns.

Among these are proximity to existing backbone and backhaul fiber plant. AT&T, for example, tends to offer gigabit services around the country to multi-dwelling units and single-family homes that are located in close proximity to its existing fiber optics.

Another factor is proximity to areas with significant potential enterprise business. As with the former factor, many companies will have invested in fiber infrastructure to areas where large enterprise customers that make big monthly purchases of services are located. As a result, neighborhoods with some proximity to these enterprise customers tend to offer better economics for new residential deployment.

The availability of aerial utility pole space is a further critical factor, so long as utility poles are in reasonably good condition and do not require costly replacement or extensive "make-ready" to prepare them for a new attachment.

Closely related to whether aerial utilities are available or not is the cost factor associated with density. The higher the density in a neighborhood, the lower the per-customer construction or upgrade costs (all other things being equal); obviously the savings associated with density can be negated by the potential higher costs of expensive pole replacement and make-ready or costly underground construction.

Another related factor is the type of housing in the neighborhood, and whether it is single family or MDUs. Construction to MDUs can be more cost-effective, assuming that the inside wiring in the building is usable for new broadband purposes, and that the service provider has access to the market in the MDU. (This is frequently not the case—but San Francisco became the first city in the country to pass a law regulating a tenant's right to choose communications services and access to the inside wiring owned by the property owner.)

Finally, demographics play a significant role in private sector investment calculus around broadband upgrades or expansion. Again, all other things being equal, families with higher levels of education, multiple breadwinners, multiple children of internet-use age, and so on tend to be high-revenue customers for broadband internet service. Neighborhoods and cities in which these potential customers are concentrated are of particular interest to private investors. In San Francisco, these demographic factors will play less of a role than in other cities, where the overall demographic factors are less attractive than in San Francisco.

The totality of these and other factors will impact private deployment. In a model in which the City leaves broadband investment entirely to the private sector, other than through some facilitation or other low-cost strategies, these factors rather than the City's policy priorities around digital opportunity, digital equity, and universal access will determine deployment patterns.

4.9 Benefits and Challenges of the Private Investment Model

The foremost benefit of the private investment model is private investment and lack of City financial risk. To the extent that the private market delivers new broadband capabilities and new broadband competition, the City is in a position to partially or incrementally meet its policy goals without risk to the taxpayers. That said, as is discussed throughout this document, private investment is an uneven and incremental solution, rather than a comprehensive and universal approach.

Along with the benefit of not having to fund or finance a broadband network, the private solution can deliver the considerable benefits of private sector innovation and creativity. Particularly in a singular market like San Francisco of early adopters and technology-adept citizens, private networks in theory will respond to the capabilities of the market through service innovation and creativity. We note, though, that the broadband market has historically seen less of this kind of innovation than one would want, given lack of competition and opportunity for network operators to use the monopoly or duopoly status to protect existing business models and revenue streams.

The modest emerging competition in some parts of San Francisco will hopefully continue to impact that static dynamic, as has been the case to some extent in markets throughout the country since the early Google Fiber announcements stimulated modest new investment by incumbents. But the incremental increases in competition in some parts of the City would not have the same transformative impact with regard to competitive service delivery and innovation as would a comprehensive, universal citywide deployment.

Among the considerable challenges, from the City's standpoint, of leaving broadband to a largely noncompetitive private market is the deeply uneven benefit to some communities and neighborhoods relative to others. As we have documented here, with the exception of Comcast, private sector deployment patterns are not comprehensive or consistent throughout the City. This has an impact not only in regard to services and availability, but also in regard to the affordability that is presumably created by robust competition.

4.10 Risk of Consolidation and Reduction in Competition

In the current environment, broadband competition faces political challenges. Given the regulatory environment in Washington, we are moving toward far greater consolidation and monopolization of communications infrastructure ownership.

For example, we anticipate a very friendly regulatory approach toward mergers, given the current leadership at the Federal Communications Commission and Department of Justice. Indeed, we are already seeing a wave of consolidation among enterprise providers. That consolidation began a number of years ago and is likely to accelerate, as demonstrated by CenturyLink's pending acquisition of Level 3.

We expect this consolidation to reach even further into the industry, as well. The prospect of Verizon's acquisition of either Charter or Comcast, for example, would not only reduce wireline broadband competition, but would also threaten the promised mobile competition that cable companies are planning to offer to mobile phone companies.

5 P3 Structure Could Enable the City to Achieve the Goal of Open, Ubiquitous Fiber

P3 represents a promising means by which to meet San Francisco's goals for this initiative. Policy goals such as ubiquity, openness, and pricing can potentially be negotiated with the private partner because the City's investment buys it influence.

5.1 P3 Background

P3 is a new term in broadband planning,[78] as that term is used internationally to signify an alternative delivery mechanism for financing construction and operations of a public asset.

The formal P3 Structure is largely untested in the U.S. with respect to broadband. To our knowledge, the Kentucky middle mile project is the only formal broadband P3 to have closed[79] and the only other current P3 project contemplated for FTTP (other than this initiative) is a nascent project in Topeka, Kansas, and the surrounding county.[80] P3 has been utilized for last mile broadband in parts of Asia and Europe.

In other infrastructure areas, the formal P3 mechanism has long been a preferred tool for public infrastructure projects in parts of Europe and Asia, and has gained considerable currency in the U.S. in recent years. Indeed, it appears to be potentially contemplated for the much-discussed potential Trump infrastructure bill that may emerge over the next year.

The formal P3 mechanism has been used most frequently in the areas of transportation and public transit, and is increasingly now being used for public projects like libraries, schools, government buildings, prisons, and convention centers. Formal P3s have tended to be concentrated in the United States in projects that are at least in part self-funding—projects

[78] The term public–private partnership is used in a range of ways—including to refer to less formal arrangements such as facilitation by public entities of private investment, such as Google Fiber's relationship with Kansas City, Austin, and others. But for purposes of this document and the Fiber for San Francisco Initiative, we use the term to refer to a formal negotiated structure under which a public entity selects a concessionaire to deliver, over some substantial period of time, some subset of the necessary elements of an infrastructure project.

[79] KentuckyWired is the first of its kind in the country. The network will connect 1,100 government entities over a 3,400-mile fiber optic backbone and excess capacity will be made available to private sector companies for lease, development, and innovation. Kentucky will retain ownership of the network; the concessionaire will build, maintain and operate the network for 30 years. The project is notable for its politically bipartisan support. KentuckyWired was first announced by Rep. Hal Rogers, a Republican, and then-Gov. Steve Beshear, a Democrat, in 2014. Gov. Matt Bevin, a Republican, announced his support for the project after his election in 2016. "Kentucky Wins 'Deal of the Year' for KentuckyWired Fiber Optic Project," News, CTC Technology & Energy, December 8, 2015, http://www.ctcnet.us/blog/kentucky-wins-deal-of-the-year-for-kentuckywired-fiber-optic-project/(accessed June 2017); "KentuckyWired Statewide Broadband Network Initiative Moving Forward in Eastern Kentucky and Beyond," Press Release, KentuckyWired, September 16, 2016, https://goo.gl/QxzjYx (accessed June 2017).

[80] "JEDO Board Meeting," Minutes, December 14, 2016, City of Topeka and Shawnee County, Joint Economic Development Organization, http://www.jedoecodevo.com/Meeting-Documents/2016Documents/12.14.16Agenda%20Packet.pdf (accessed June 2017).

where a revenue stream is associated with the infrastructure project, and those revenues can be applied to the public entity's financial obligation to the concessionaire.

Thus, for example, in the case of a toll road, a hypothetical P3 might anticipate certain toll revenues over a period of time that the concessionaire would collect and keep—potentially with a minimum revenue guarantee (from the state department of transportation that is the sponsor of the P3) in the event that toll revenues do not meet the negotiated targets, and potentially with revenue-sharing between public and private entities in the event that revenues exceed certain targets.

Each P3 is obviously unique, with a customized mechanism for addressing revenue risk, as well as long-term revenue upside. Similarly customized for each P3 would be allocation of a full range of risks, including construction risk and performance risk. Public entities that sponsor infrastructure P3s frequently do so in order to efficiently allocate such risks as best they can. Thus, for example, a formal P3 could potentially allocate performance risk to the private sector to get the advantage of presumed private sector efficiencies and operational capacity—while possibly still allocating some construction risk to the public partner, particularly if public processes such as permitting, access to land, and so on, are contributors to risk.

Another primary reason for public sponsorship of P3s is a scenario in which the P3 provides access to capital for the public infrastructure project. Private capital of this sort is not necessarily low cost. Indeed, it is almost always going to be higher-cost capital than would be public bond debt. But in the event that this is the most accessible or only accessible form of capital, this is a useful tool for a government to proceed with projects that otherwise would have to wait.

5.2 The Core Structure of the Formal P3

At its core, the concessionaire model represents a public grant of rights to a private partner that contracts to finance, build, and operate a broadband network, with the concession lasting a considerable period of time (likely 30 or more years). The private partner agrees to provide financing, construction, operations, and service delivery over the network.

To fund all this activity and investment, the locality agrees to an arrangement that guarantees a certain level of revenue to the concessionaire. This revenue mechanism could take any form legally available to the locality. Depending on state and local law, the locality could provide a direct revenue stream out of general funds, through a specific fee or tax, or otherwise. Alternatively, the partnership could be structured such that the private partner's revenue stream derives from end-user payments (service fees for data, voice, and video services, paid by network customers), with a minimum revenue guarantee by the locality such that any shortfall in projected revenues would be made up by the locality. Hybrid arrangements are also possible, in which the private partner's payments are funded partially through a public tax or fee and partially through end Connection Fees for services. In any event, the private partner is unlikely to assume all or most of the demand and revenue risk in a P3 arrangement.

To partially offset public risk in this regard, P3 arrangements also frequently include provision for revenue sharing in the event that network revenues exceed the minimum amounts guaranteed to the private partner.

Some communities that have considered P3s have sought "easy out" scenarios in which the locality can cancel the partnership or choose not to appropriate necessary funds in any given year, and thus depart its financial obligations at any time. But without the public entity's long-term financial commitment, this approach is unlikely to be marketable.

5.3 Applying the Formal P3 Model to Broadband Creates Some Risks

The application of the formal P3 model to broadband is still new and untested in the U.S. with respect to last-mile broadband, which is not an area of traditional public sector operations. Thus, for example, unlike roads, bridges, and subway systems, broadband represents an infrastructure category that has largely (though not exclusively) been the province of the private sector. As a result, a formal P3 in the context of broadband faces certain analytical and practical challenges that are not experienced in the same way in other P3 sectors.

As a result, traditional P3 risk modeling for municipal infrastructure is insufficient as applied to broadband. In a water, sewer, or tollway project, one typically considers traditional financing factors and the type of demand that exists in a monopolistic environment. Furthermore, in those infrastructure categories, the services provided are largely stable and predictable (a water utility will provide water for its entire lifetime, and a toll road will provide transit for vehicles for its entire lifetime). This, however, is not the case in broadband, an industry in which the ways in which consumers use the product is constantly in flux and the services provided over the network are predictable only in the short to medium-term. Note, for example, the decline of cable television as a service as consumers move to internet-based video streaming services such as Netflix and Hulu. Similarly, wireline phone service, once a universally-adopted service, is now used by as few as half the homes in technology-adept markets.

Indeed, applying P3 to FTTP introduces a range of critical market and demand risks. Because right alongside the City's network, private competitors operate their own networks, even though none offers ubiquitous fiber, so the services they offer will not match what is possible over the FTTP network that the City envisions. And both the City-sponsored network and private competitors have to grapple with, and adapt to, constant and substantial changes in consumer demand, service preferences, and technology change. These factors are dramatically different to those impacting revenue risk in a formal P3 in a more traditional sector such as water or public transit.

6 P3 Model Analysis

This section of the report provides an analysis regarding application of alternative delivery models to the City's proposed FTTP project. P3s have never before been applied to FTTP projects in the United States, though the idea has been considered in a number of communities. As a result, this is a first-of-its-kind analysis. In this section, we describe the City's guiding principles and the principles of rigorous financial modeling that shaped the analysis and recommendations. We summarize our analysis and the alternatives we considered, including the typical infrastructure P3 model (the "Classic P3 Model"), and describe our recommendations for two alternative means by which to apply P3 to FTTP.

6.1 Framework Goals Used to Develop Potential Project Delivery Models

We set aside standard thinking about broadband P3s to develop framework goals that would guide our assessment of potential approaches—and, ultimately, the creation of a completely new broadband P3 model that meets the City's goals and creates a feasible investment vehicle for private partners. Our three framework goals are as follows.

6.1.1 Create a Broadband Market That Provides Long-Term "Best Value" for Taxpayers, Users, and the City

We seek to create long-term "best value" for the City by creating a level playing field and competitive market at the service level and, ideally, at the dark fiber level, which we believe will lead to reduced costs and improved services for users. To achieve true competition, the model would need to support the entry of multiple service providers.

Some level of City and/or taxpayer support will be necessary for a project of this size and nature—but enabling additional ISPs and application providers to enter the market will likely yield more revenues and lessen the financial burden on the City and its taxpayers.

To ensure that this principle remains in place over the long term, we seek flexibility to accommodate changes over time—in terms of technology (which will improve over time) as well as supply and demand for services.

6.1.2 Create a Feasible Business Case for the Project

Investments in the project will be significant—and the project's revenues will need to be sufficient to not only recover the investments, but also to cover operational costs and compensate parties for absorbing risks.

The guiding financial question, then, is how to minimize life cycle costs as much as possible, generate enough revenues, and reduce the project's risk profile. These outcomes are not a given, but can be optimized by scoping the project with these needs in mind, and by structuring its funding mechanisms, financing structure, and delivery model.

6.1.3 Create a Structure That Can Be Financed

As a fundamental starting point in our planning, we recognize that the City does not want to retain all risks and finance the project itself; rather, the City seeks to use private financing and to transfer some risks to the private sector.

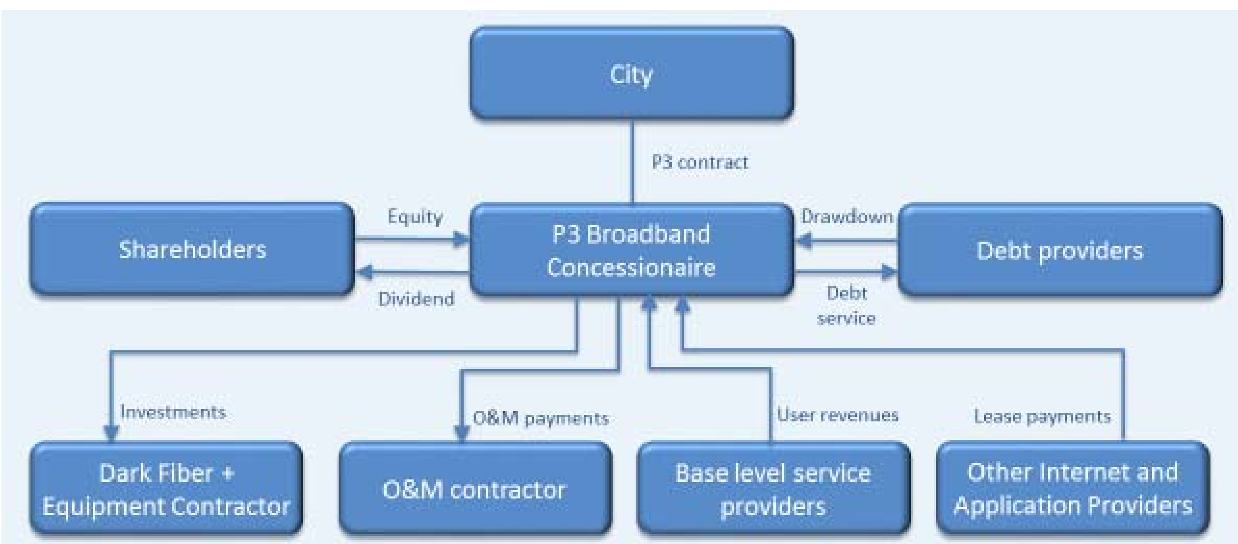
That said, construction and revenue risk for a project such as this are very significant; this high risk profile may be difficult or impossible for financiers and investors to accept.

As a consequence, financing costs may be extremely high, or the deal may not be financeable at all. Therefore, the project needs to be structured such that it leads to a risk profile that is acceptable to financiers and investors.

6.2 Classic P3 Model Illustrates Limitations of Broadband P3 Approaches

As a benchmark, we began our analysis of broadband P3 options with the "classic P3" model—a "middle mile" variation of which was first successfully negotiated for a broadband initiative by the Commonwealth of Kentucky in granting a middle mile fiber concession to Macquarie Capital in 2014.[81] In our use of the term "classic model," we are referring to the fact that there exists a general framework for P3s across different asset classes and sectors such as public utilities, social infrastructure, public transit, and transportation. In the case of the Kentucky project, the asset class (fiber optics) is of course different, as are the type of entities that will lease and use the asset, but the concept and general P3 structure are the same.

Figure 12: Classic P3 Model



As is illustrated in Figure 12, the City would negotiate a long-term contract with a P3 broadband concessionaire. The concessionaire would be responsible for delivering a turn-key solution,

[81] CTC was an independent consultant to the Commonwealth of Kentucky in its negotiations with Macquarie.

including the outside plant infrastructure, lighting of the network, and provision of all operations and services. In other words, the concessionaire would design, construct, finance, operate (i.e., deliver services to end users and/or sell capacity to competing ISPs to deliver services), and maintain the network. The City would sponsor the infrastructure,[82] but the concessionaire would control access to it under negotiated and agreed-upon terms with the City.

The City would achieve some of its primary goals under this model—including the construction of a future-proof fiber optic broadband network and delivery of services to residents and businesses. The City's contract with the concessionaire would also shield the City from some long-term project risks. The concessionaire would hold the long-term performance risks associated with the project, as well as revenue risks (e.g., commercial revenue from base level service providers, lease payments from other internet and application providers).

That said, pursuing the Classic P3 Model has some shortcomings:

1. **Limited competition reduces long-term value**

Because the concessionaire is completely responsible for services over the infrastructure—delivering base level services to all households and businesses, additional retail services, and wholesale services to service providers—this model limits competition. This is an issue for creating a level playing field with respect to retail services, and for incentivizing a competitive market that can effectively drive down prices for end users and offer the other benefits of competition.

In addition, there may be limited ability to accommodate changes over time due to the long-term nature of P3 contracts. This may not be as important of an issue at the dark fiber level, as fiber represents a long-term asset and has a longer replacement life cycle. But for investments in network equipment, operations, and service provision, the economic life of this equipment is only seven to 10 years—which is hard to accommodate within a long-term P3 concessionaire model.

2. **Uncertain revenues increase risk to project business case**

Potential commercial revenues under this model are uncertain, due both to the unpredictable nature of broadband equipment and network technologies and the maturity of the San Francisco market.

In this model, for example, the concessionaire would hold risks associated with commercial revenue from base level service providers, and lease payments from other internet and

[82] The term sponsor comes from the term "Project Sponsor" which is the entity with the overall accountability for the project. In this case, the City of San Francisco is the sponsor of the project. The City has ultimate responsibility, and is accountable to the public / taxpayers.

application providers—which are uncertain revenue streams. This is unfavorable for the project's business case.

Dedicating revenue from users could reduce the revenue risk profile for the P3 concessionaire, but would only partially mitigate the risk.

3. Risk mitigation required to attract investors and financiers

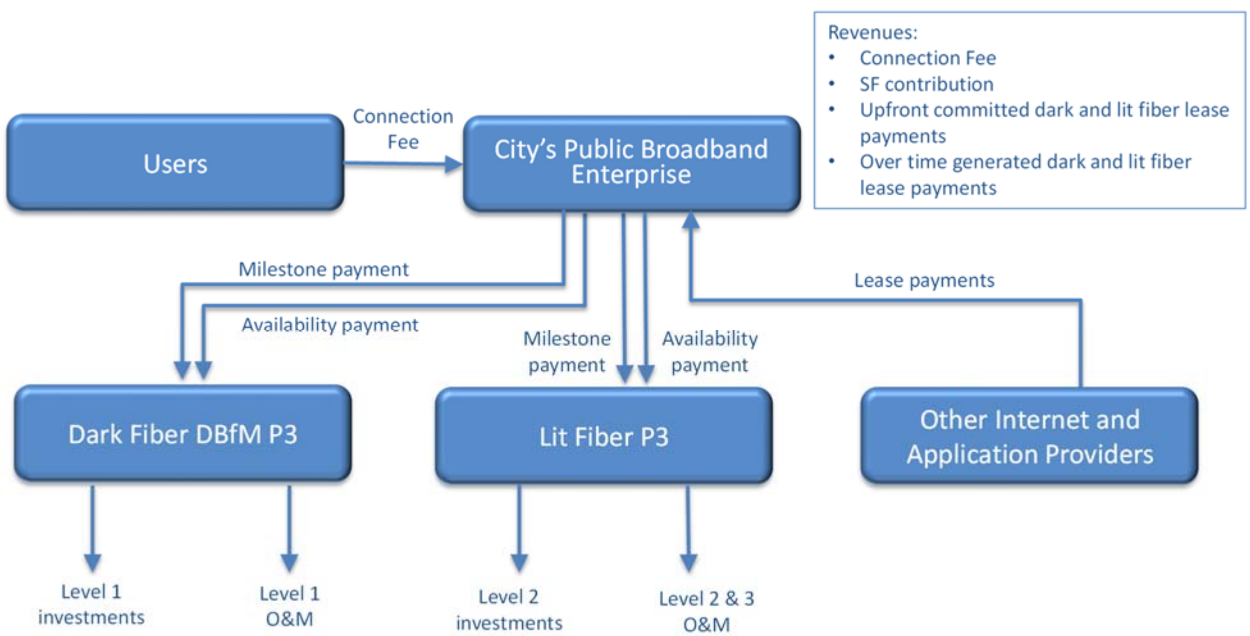
Due to the uncertain revenue streams created by this model, financing a project using this approach would be quite challenging. It is unlikely that financiers and investors will be willing to invest unless they would have a "quasi-monopoly," including rate-setting powers, and/or some type of contribution from the City (e.g., a guarantee, risk-sharing mechanism, or partial payment) to mitigate risk.

7 Alternative P3 Approach: Dual P3s for Dark and Lit Fiber

To ameliorate the Classic P3 Model's shortcomings in the broadband environment, and to maximize the potential benefits of the P3 structure for FTTP, the Project Team developed a new P3 approach for consideration by the City.

The approach is a dual structure that includes two separate P3s (Dual P3 Model). The Dual P3 Model (Figure 13) seeks to address the challenges inherent in the other models by reimagining the established infrastructure P3 and creating two separate P3s for the project—one for the dark fiber investments (Dark Fiber P3) and one for the equipment, operations, and service provision investments (Lit Fiber P3).

Figure 13: Dual P3 Model



7.1 Overview of the Dual P3 Model

The Dual P3 Model recognizes that the most critical challenge in the Classic P3 Model is the disparate risk profiles associated with the dark fiber investments on the one hand, and the equipment/network operations/service provision investments on the other. Combining these two distinct risk profiles within one P3 is highly challenging, and would encumber the business case for the project. As a result, the Dual P3 Model comprises two separate P3 contracts:

3. Dark Fiber P3: Includes design, build, partial finance, and operations and maintenance (O&M) of dark fiber and other passive outside plant such as communications huts and splitters. This is a long-term P3 contract (e.g., 30 years) for dark fiber/outside plant investments; it potentially leverages partial public financing.

4. Lit Fiber P3: Includes design, build, and O&M of network electronics investments, and provision of a base-level of service, as well as provision of wholesale services to Retail Service Providers who will compete over the network. This is a shorter-term P3 contract designed to enable responsiveness to technology change and the need to replace network electronics every seven to 10 years.

This model recognizes that the risk profile for constructing and maintaining a fiber network is different from the risk profile associated with providing services over the long term in a commercial broadband market. The P3 for the dark fiber/outside plant investments can be separated from the P3 for electronic equipment, network operations, and provision of base-level service because interrelationships between the two are limited. This approach results in a more explicit distinction between the dark fiber network provider and the operator/service provider on that network, with the intent to enable more technological flexibility and competition at in network operations and service provision.

7.1.1 Potential Participating Entities

The Dual P3 Model assigns roles to a wide range of participants. The **City and County of San Francisco** would be the sponsoring agency—providing an oversight role, and paying the concessionaire for services to the City. The City is ultimately accountable to the residents and taxpayers of the City, who are the intended users and beneficiaries of this project.

Residents and businesses in the City of San Francisco would fund some of the infrastructure through some form of assessment, utility tax, property-related fee, parcel tax, or any type of approved revenue initiative.[83] If a property-related fee is applied, then provisioning of base-level services will need to be included in the P3 to justify the fee.[84]

A **public broadband entity** (Public Broadband Enterprise) would be created by the City to manage the multiple P3 agreements, organize leasing of the assets, and oversee lease payments and other financial transactions. This role could be taken by a City agency (existing or newly created) or some other public entity, potentially even including (limited) private involvement.[85] The Public Broadband Enterprise could also receive users' property-related fees or parcel tax payments and issue public financing, if that approach is selected. Alternatively, receipt of fees and issuance of

[83] In consultation with the City Attorney's office, the Project Team developed a matrix and business analysis of potential funding mechanisms that is included in the appendices to this report.

[84] See Section 7.3 for more detail.

[85] In order to help maximize the value at the system level, it would be an option to have involvement from private shareholders. A potential way to structure this would be to start off by selling a small percentage of the Public Broadband Enterprise's shares. Private ownership could potentially be expanded over time (when the risk profile decreases and the value of the Public Broadband Enterprise shares is expected to increase).

financing could be fulfilled by a **non-profit corporation** that works in parallel with the Public Broadband Enterprise.[86]

Internet and application service providers (ISPs and ASPs) would include any entity that makes a payment for access to dark or lit fiber. These may include large corporations, institutions (e.g., universities), and service providers of a range of sizes, including some that are very small but who are able to compete over the network by purchasing wholesale services from the Lit Fiber Concessionaire.

The **dark fiber design, build, finance, maintain (DBfM) concessionaire** (Dark Fiber Concessionaire) will provide investments in dark fiber and other outside plant assets and, following construction, outside plant operations and maintenance (O&M).

A **base-level service concessionaire** (Lit Fiber Concessionaire) will provide equipment and O&M investments, and will deliver both base-level services to homes and businesses and wholesale "lit fiber" services to other ISPs. Importantly, this partner will be precluded from delivering retail services other than base-level services.

7.1.2 Financial Flows

The Dual P3 Model is similar to the Classic P3 Model in that it will include some financial features that were crafted to address issues that are universal to the Fiber for San Francisco Initiative, regardless of the P3 model. This model:

- Attributes a fixed partial payment from the City to the project (i.e., the City will commit to some level of dedicated funding of the project) to mitigate the concessionaires' high risks of uncertain project revenues
- Provides a minimum revenue guarantee from the City
- Allows for upfront lease payments to be agreed upon by the City and other internet and application providers

The City will be in a position to make a contribution for data services it receives from the concessionaire and that are currently procured from other parties in the form of leased circuits. The amount of that contribution would potentially be based on avoided costs, and while we have not been provided data in this regard, based on experience in other cities, we estimate the amount to be in excess of $10 million per year.

[86] For more information on 63-20 corporations, see: http://www.financingtransportation.org/funding_financing/legislation_regulations/state_legislation/non_profit_63_20.aspx

San Francisco's residents and businesses will also provide some type of dedicated funding, for both the Dark Fiber P3 and the Lit Fiber P3. If a property-related fee is used, then provision of base-level services is needed to justify the fee, and provision of base-level services will need to be included in the P3.

The Lit Fiber Concessionaire would be responsible for a combination of equipment investments, maintenance, and base-level service provision. Additional financial flows include:

- City payments to the Dark Fiber Concessionaire
  - Milestone payments: Payments from the public entity to the Dark Fiber Concessionaire for the dark fiber construction
  - Availability payments: Periodic payment to the Dark Fiber Concessionaire for making the infrastructure available at agreed upon standards for the duration of the P3 contract
- City payments to the Lit Fiber Concessionaire
  - Service payment: Periodic payment to the Lit Fiber Concessionaire for providing services at the agreed upon standards for the duration of the P3 contract

In terms of financing, we believe the Dark Fiber P3 would require partial public and partial private financing, given the high cost of the dark fiber network. We believe that the required investments for the Lit Fiber P3 can be delivered through private financing.

7.1.3 Key Contractual Elements

7.1.3.1 Terms / periods

No technological flexibility is necessary at for the dark fiber/outside plant because fiber technology is not expected to be a limiting factor; therefore, a long-term contract is suitable.

In contrast, for network equipment, operations, and service provision, a relatively short contract term would allow for flexibility to modify standards over time to address future technological changes. The economic life of network equipment is seven to 10 years, depending on the type of equipment—so this P3 concession should ideally be re-procured every seven to 10 years to maintain technological currency. This regular revision of technical standards—and continuous competition—will increase the likelihood that San Franciscans will receive a high quality of service and the latest technical standards at attractive rates.

To further promote competition, the equipment that is part of the Lit Fiber P3 would be transferred to the Public Broadband Enterprise at the end of the contract term and would be available to the Lit Fiber Concessionaire selected for the new term; detailed information about the equipment and its condition would be part of the RFP for the next Lit Fiber P3 so as to enable all bidders to build the information into their planning and bids.

7.1.3.2 Elements

As is discussed in detail in the procurement strategy section of this report, we recommend that, prior to launching the P3 procurements, the City undertake a leasing process to secure third party revenues for dark fiber (and potentially lit fiber wholesale services). This approach would further improve financial feasibility of the project and ensure a more level playing field for P3 bidders.[87]

7.1.3.3 Allowable activities/generating additional revenues

In the Dual P3 Model, concessionaires may deliver only specific services; they are prohibited from engaging in other activities.

To maximize revenues, revenue incentives can be included in either the Lit Fiber P3 or both P3s. P3 bidders should have an incentive to secure additional revenues during the bidding process; securing more revenues upfront can reduce the fee or tax to be charged for establishing the fiber network and delivering a base-level service.

P3 concessionaires should also have an incentive to generate more revenues over time. Providing an incentive rather than transferring all revenue risk to the P3 concessionaire will presumably encourage the concessionaire to maximize revenue risk over time, without creating an excessively high-risk profile that results in very high financing costs.

7.2 How the Dual P3 Model Addresses the Project Principles

Splitting the project into two separate P3s **maximizes long-term value by increasing competition**. Having a separate Lit Fiber P3 that is re-procured every seven to 10 years (matching the economic life cycle of the electronics in the network) maximizes competition, creating more long-term value for the City. Re-procuring the Lit Fiber P3 will also help to create a level playing field among competing service providers, and incentivize a competitive market that can effectively drive down prices for end users.

This model **creates a feasible business case, with more certainty regarding revenue,** through an upfront sale or pre-lease of dark fiber and other network capacity, in which the City will seek to secure commercial revenues prior to procurement—such that all potential bidders have some dedicated commercial revenue to include in their proposed projects. Absent this pre-P3 sale, potential commercial revenues (dark fiber lease fees, fees for wholesale lit access to customers) would be highly uncertain, due both to the unpredictable nature of broadband technology development and broadband services, as well as the relative maturity of the San Francisco market. Splitting the project into two separate P3s also mitigates some of the risks associated

[87] Section 9.1 provides detail regarding this consideration.

with long-term uncertainty for revenue streams by making a shorter term P3 for the Lit Fiber portion of the project.

This model also **creates a structure that can likely be financed**. By separating the project into two P3s, the recommended model also separates two distinct risk profiles—making the project more attractive to investors and financiers, who can choose to invest in the P3 with a risk profile most appropriate to their risk appetite. Additionally, the actions taken to create more certainty regarding revenues can alleviate some of the pressure that financiers and investors would have put on the project to have a "quasi-monopoly," including rate-setting powers, and/or some type of contribution from the City (e.g., a guarantee, risk-sharing mechanism, or partial payment) to mitigate risk.

7.3 Financial Analysis and Models of Dual P3

As part of the analysis for the Fiber for San Francisco Initiative, the Project Team analyzed the financial feasibility of the Dual P3 Model, based on our construction cost estimates for full FTTP deployment. This section is a description of the financial analysis, including assumptions, and preliminary financial results and sensitivities.

Financial feasibility analysis is typically conducted to understand the financial implications of the project. Specifically, the financial feasibility analysis of this project seeks to answer the following questions:

- Given the capital and operations costs for the project, what is the expected residential fee per passing?
- Given the capital and operations costs for the project, what is the expected business fee per passing?
- How do cost variations (for example, low-income subsidy or increasing capital costs) influence these fees?
- How do revenue variations (for example, from upfront commitments or from City resources) influence these fees?
- What is the expected annual availability payment to the P3 concessionaires?

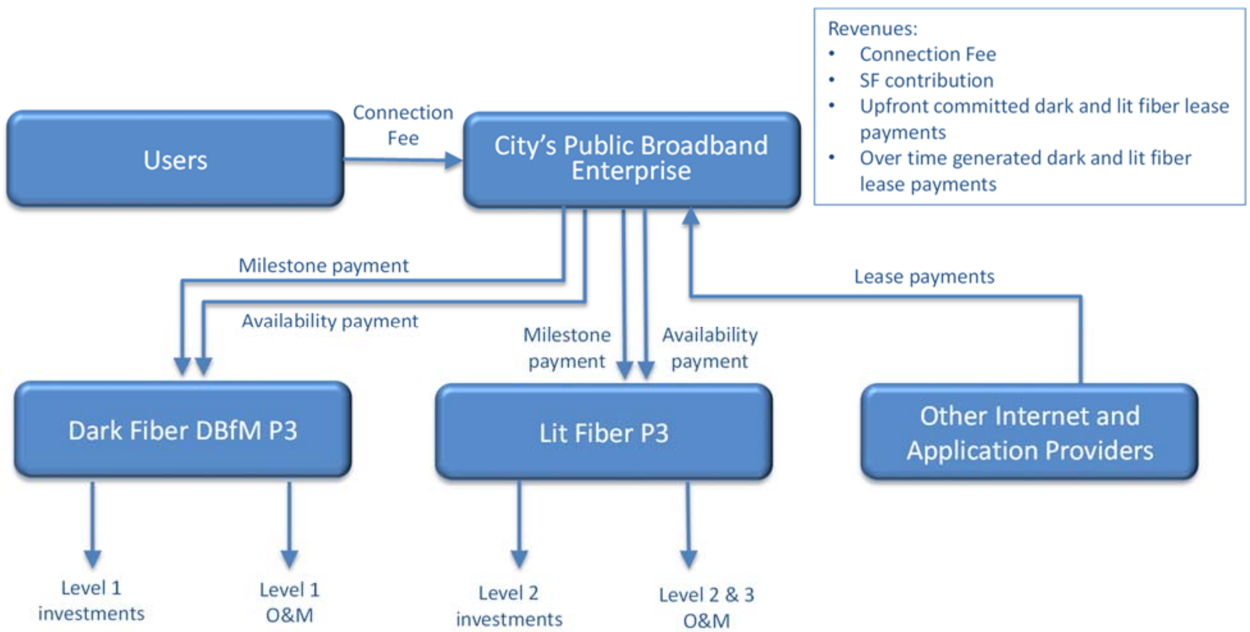
Currently, the project is at the pre-procurement stage, where answers to the questions above can help decision-makers understand whether to proceed with the project. Specifically, the expected fees per passing influence the Connection Fees. The level of the Connection Fee can help decision-makers understand the feasibility of this project from a political standpoint.

The foundation of the financial feasibility analysis is a financial model that was tailor-built for this project—and based on a "base case" consisting of preliminary assumptions. More in-depth project preparations are needed, including an industry sounding and a pre-procurement sale process to firm up assumptions on costs, potential upfront revenues, public resources, subsidy, financing conditions, and so on. The financial model and subsequent financial feasibility analysis do not include an analysis of the City's financial resources for this project.

7.3.1 High-Level Overview of Cash Flows in Broadband P3 Model

Our analysis is based on the Dual P3 model, consisting of two separate P3s, as described above.[88]

Figure 14: Dual P3 Model



The Dual P3 Model also includes a Public Broadband Enterprise (PBE). The PBE manages the multiple P3 agreements, organizes an upfront lease sale, and oversees lease payments and other financial transactions. This role could be taken by a City agency (existing or newly created) or some other public entity.

Key financial flows in this model consist of the following:

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[88] Dark Fiber P3: Includes design, build, partial finance, and operations and maintenance (O&M) of dark fiber and other passive outside plant such as communications huts and splitters. This is a long-term P3 contract (e.g., 30 years) for dark fiber/outside plant investments.
Lit Fiber P3: Includes design, build, financing and O&M of network electronics investments, and provision of a base-level of service, as well as provision of wholesale services to retail service providers who will compete over the network. This is a shorter-term P3 contract designed to enable responsiveness to technology change and the need to replace network electronics every five to 10 years.

- City payments to the Dark Fiber Concessionaire
    - Milestone payments: Payments from the PBE to the Dark Fiber Concessionaire for the dark fiber construction
    - Availability payments: Periodic payment to the Dark Fiber Concessionaire for making the infrastructure available at agreed upon standards for the duration of the P3 contract
- City payments to the Lit Fiber Concessionaire
    - Availability payment: Periodic payment from the PBE to the Lit Fiber Concessionaire for providing services at the agreed upon standards for the duration of the P3 contract

All City payments to both concessionaires will come from the PBE. The PBE will be funded through:

- Connection Fees – the payments from households and businesses to fund the P3s, most likely structured in the form of a property related fee, or parcel tax
- Possible service fees from the City for use of the broadband network—similar to existing costs that the City incurs for current broadband services

Potential payments/revenues associated with this project include:

- Lease payments for dark and or lit fiber from lessees that are committed upfront via the pre-procurement sale
- Additional lease payments/revenues confirmed by either concessionaire

7.3.2 Assumptions per Entity

7.3.2.1 General Assumptions

The Project Team assumes that the project will begin after an appropriate project preparation, analysis, and procurement period. The main assumption for the base case is that the project's costs are funded by Connection Fees and potential additional revenues—however, these potential additional revenues are unknown at this time. The model is currently a "flat model," assuming no indexing of costs or revenues for inflation.

7.3.2.2 Assumptions for Dark Fiber P3

7.3.2.2.1 Timing

Construction of dark fiber is assumed to occur over three years. As dark fiber infrastructure is installed, it will be made available for use. Therefore, an appropriate proportion of associated operations and maintenance costs will be incurred as dark fiber infrastructure is installed over the three-year construction period. Logically, the availability payment for the dark fiber infrastructure, made to the concessionaire, will also be provided in proportion with the percentage of infrastructure made available. We assume a construction ramp-up profile as follows: year 1, 30 percent; year 2, 50 percent; year 3, 20 percent. The operations period of the infrastructure is 30 years from completion of construction.

7.3.2.2.2 Capital Expenditures

For the base case used in this financial feasibility analysis, the total estimated capital expenditure is approximately $1.5 billion. These costs represent the equipment, material, and construction labor associated with building, and implementing a dark fiber network.

Table 17: Base Case Dark Fiber P3 Capital Expenditure

Dark Fiber P3 Capital Expenditure Elements	Description	Base Case Cost
Outside plant	Engineering, QA/QC, general outside plant construction, special crossings, backbone and distribution plant splicing, backbone hub, termination, and testing, FTTP service drop and lateral installations.	$776 million
Customer premises equipment	Assumes residential drops (354,807 passings) and business drops (18,674 passings)	$728 million

7.3.2.2.3 Operational Expenditures

Operations expenditures for the dark fiber infrastructure have various timing profiles. Some operational expenditures are linked to the ramp up profile of the capital expenditures (for example, for fiber and network maintenance), while others are linked to a separate ramp-up profile: year 1, 50 percent; year 2, 50 percent (for example, for office expenses). Annual operations cost after construction is approximately $23 million. This includes labor, insurance, offices, facilities lease, locates and ticket processing, contingency, fiber and network maintenance, legal, consulting, education and training, and pole attachments.

7.3.2.2.4 Revenues

Revenues for the Dark Fiber P3 consist of two main sources, milestone payments during construction, and availability payments as the dark fiber infrastructure is made available. For the base case, the Project Team assumed two milestone payments at the end of the second and third year of construction, totaling $1.4 billion. This assumption was made based on the Project Team's professional judgement that the P3 market would expect that the milestone payment from the City would fund approximately 90 percent of capital cost.[89]

Availability payments will be transmitted to the Dark Fiber Concessionaire from the PBE. It is optimized to cover for all costs, except for the majority of construction—which is covered with the milestone payments as described above. Availability payments will commence in year 1, as 30 percent of the dark fiber network is deployed, and will ramp up to full payment of $36 million, in line with the capital expenditure ramp-up profile.

For the base case, no additional lease payments from lessees, or additional payments from the City are assumed.

7.3.2.2.5 Financing

Based on the Project Team's experience with P3 transactions in other sectors, we expect that the market will be receptive to a broadband infrastructure project that features partial public and partial private financing—meaning that the public sector will fund a portion of the capital cost of the project. Based on experiences in other P3 projects, the Project Team anticipates that the public sector can fund approximately 90 percent of the capital cost of the project while still enjoying the benefits of private financing related to effective risk transfer and performance incentives. As such, we have assumed milestone payments from the PBE to the Dark Fiber Concessionaire equal to 90 percent of the capital cost.

Private financing for P3 projects typically comprises of a combination of private equity and debt. Based on the Project Team's experience with other P3 projects, we expect that the private finance structure will be highly leveraged, with 90 percent debt and 10 percent equity in the base case. The Project Team anticipates that the Dark Fiber P3 concessionaire will use a bridge loan to meet the portion of the financing that will be repaid with milestone payments.

7.3.2.3 Assumptions for Lit Fiber P3

7.3.2.3.1 Timing

The Lit Fiber P3 concession is assumed to have a seven-year contract duration—with subsequent Lit Fiber P3 procurements. For this financial analysis, the Project Team chose to model only the first lit fiber concession because it is difficult to predict market expectations and assumptions

[89] Please see Section 7.3.2.2.5 for a detailed explanation.

seven years into the future for a market such as broadband that has such fast-changing technological requirements.

Construction of lit fiber infrastructure is assumed to begin in 2020, one year after the Dark Fiber P3 starts, with a two-year construction duration. As dark fiber infrastructure is installed, it will be made available for use—and the Lit Fiber Concessionaire will follow with its construction accordingly. Therefore, an appropriate proportion of associated operations and maintenance costs will be incurred as the lit fiber infrastructure is installed over the two-year construction period.

The operations period of the infrastructure is five years from completion of construction—totaling to a seven-year contract duration.

7.3.2.3.2 Capital Expenditures

For the base case used in this financial feasibility analysis, the total estimated capital expenditure for the Lit Fiber P3 is approximately $360 million. These costs represent the equipment, material, and labor associated with building and implementing lit fiber infrastructure over dark fiber.

Table 18: Base Case Lit Fiber P3 Capital Expenditure

Lit Fiber P3 Capital Expenditure Elements	Description	Base Case Cost
Network equipment	Core network equipment, distribution and access equipment (GPON)	$112 million
Last mile and customer premises equipment	CPE for residential, CPE for businesses, and additional annual replacement capital	$247 million

Reinvestments and major maintenance of the lit fiber infrastructure is implicitly included by using the same availability payment that is required to completely recover the investments in the first contract term for subsequent contracts. This allows for the complete renewal of the lit fiber infrastructure every seven years.

7.3.2.3.3 Operational Expenditures

Operations expenditures for the lit fiber infrastructure is assumed to start in 2020, one year after the commencement of the dark fiber contract. We assume a ramp-up profile as follows: 2020 – 50 percent, and 2021 – 50 percent.

Annual operations costs after construction is estimated to be approximately $21 million. This includes labor, insurance, utilities, office expenses, facility leases, locates and ticket processing, contingency, legal fees, consulting fees, education and training, and vendor maintenance contracts.

7.3.2.3.4 Revenues

Revenues for the Lit Fiber P3 consist of two main sources: milestone payments during construction, and availability payments as the lit fiber service is made available. For the base case, the Project Team assumed two milestone payments at the end of each construction year, totaling $147 million. This assumption was made based on the Project Team's professional judgement that the P3 market would expect that the milestone payments from the City would fund approximately 50 percent of capital cost.[90]

Availability payments for the lit fiber infrastructure and service will also be provided in proportion with the percentage of infrastructure made available, commencing in 2020 with 50 percent of the availability payment, further ramping up to the full availability payment in year 2021.

For the base case, neither additional lease payments from lessees, nor additional payments from the City, are assumed.

7.3.2.3.5 Financing

Just like for the Dark Fiber P3, we expect that the market will be receptive to a Lit Fiber P3 project that features partial public and partial private financing—meaning that the public sector will fund a portion of the capital cost of the project. Because the Lit Fiber P3 has a shorter duration, and lower capital costs, the Project Team anticipates that approximately 50 percent of the capital cost of the project will need to be funded by the public sector, and as such we have assumed milestone payments from the PBE to the Lit Fiber Concessionaire equal to 50 percent of the capital cost.

Private financing for P3 projects typically comprise a combination of private equity and debt. Based on the Project Team's experience with other P3 projects, we expect that the private finance structure will be leveraged with approximately 90 percent debt, 10 percent equity. Other financing conditions are assumed to be similar to transactions with a very similar risk profile that the Project Team has observed in comparable P3 sectors.

7.3.2.4 Assumptions for Public Broadband Entity

The PBE manages the multiple P3 agreements, organizes the fiber leasing process, and oversees lease payments and other financial transactions. This role could be taken by a City agency (existing or newly created) or some other public entity. The PBE could also receive users' property-related fees or parcel tax payments and issue public financing, if that approach is selected. Alternatively, receipt of fees and issuance of financing could be fulfilled by a non-profit corporation that works in parallel with the PBE. Therefore, this entity will not incur any capital

[90] A detailed explanation can be found in Section 7.3.2.2.5.

expenditure, but will have operational expenditures and revenues, as detailed in the following sections.

7.3.2.4.1 Operational Expenditures

Operational expenditures for the PBE include three categories of costs: payments to the P3 concessionaires, operations costs, and cost of subsidies for target populations. Payments to the P3 concessionaries include: milestone payments to both Dark Fiber and Lit Fiber Concessionaires, availability payments for the Dark Fiber P3, and availability payments for the Lit Fiber P3.

Currently, operational costs for running this department or entity (e.g., labor costs) have not been included due to lack of information. This information should be included in future updates of the analysis and include costs for staffing, running the department, collecting fees, and so on.

The overall project includes subsidies for target populations. The base case assumption is that 15 percent of residential passings are eligible for subsidy. In order to provide subsidies that can bring the residential Connection Fee down to $10 per month, the PBE will need to provide $486 annually per each eligible residential passing. The annual cost of the subsidy at full deployment is approximately $26 million.

7.3.2.4.2 Revenues

Revenues for the PBE are anticipated to include Connection Fee revenue, additional lease revenues, and contributions from the City. However, for this base case, the Project Team has only included Connection Fee revenue, as additional lease revenues, and contributions from the City are unknown at this point.

Connection Fee revenue is anticipated to net $266 million per year by year 4 (full operations). Connection Fees are anticipated to be implemented in the form of dedicated revenue provided by the City—and are accounted for as a per passing fee. The total number of residential passings assumed is 345,807.

Business passing fees were estimated using the assumptions shown in Table 19 below. For business passings, there is an additional assumption of 2 percent bad debt (inability to collect the Connection Fee).

Table 19: Base Case Business Passing Fee Assumptions

Maximum number of employees	No. of passings	Multiplier (%)
4	24,478	100
9	9,445	150
19	4,375	200
49	2,373	300
99	827	300
249	478	500
499	150	500
999	54	700
4,999	66	1,000
9,999	6	1,000
9,999 and above	13	1,000

7.3.2.4.3 Financing

The Project Team anticipates that the City will need to issue bond financing in order to meet its substantial obligations in the early years of the project due to the milestone payments for capital expenditures to the two P3 concessionaires. Based on the Project Team's experience as financial advisors for both municipal governments, and P3 transactions, the Project Team anticipates that the bond issuance associated with this project can, and should, be structured as a revenue bond. This is due to the assumption that Connection Fees structured as parcel taxes or property taxes will be dedicated to the repayment of this bond.

The bond service duration is assumed to be 27 years, with major drawdowns in years 2 and 3 of the project in order to pay milestone payments. As is typical of revenue bonds, we assume 3.5 percent interest, and minimum DSCR of 1.2.

Currently, the Project Team does not anticipate that a debt service reserve account is needed due to the significant cushion that the Connection Fee provides.

7.3.3 Results

One key financial output of the business case for this FTTP initiative is the Connection Fee that will be required to make the project feasible. Financial indicators that inform that output are the payments that the P3 concessionaires will need to cover their investments and operational expenses, meet their financing obligations, and make an appropriate return on equity vis-à-vis the various project risks that they are accepting under the P3 agreements.

All the inputs presented in the previous section are uncertain, which is common for this stage of the project development. This is why the results are shown in ranges rather than exact outcomes. For the purpose of the sensitivity analysis we show a base case, which is based on the assumptions as described in the previous section.

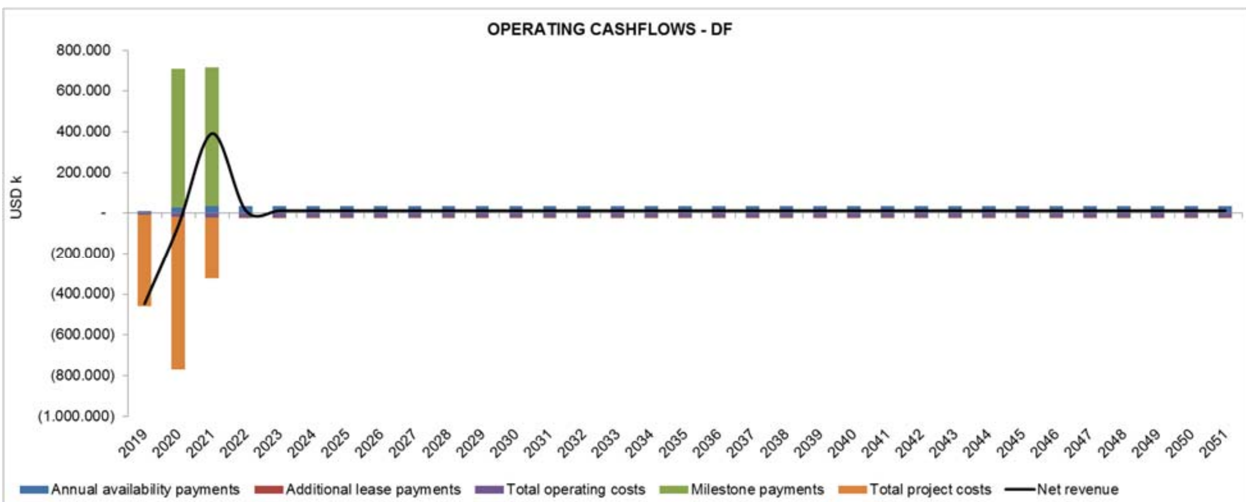
The uncertainties can be further reduced and the ranges will become narrower as the result of further project preparation. The results of the pre-procurement sale of capacity will significantly reduce the uncertainty and so will the ultimate results of the P3 procurements.

To contribute to a better understanding of the impacts of the various uncertainties, this section also presents a sensitivity analysis.

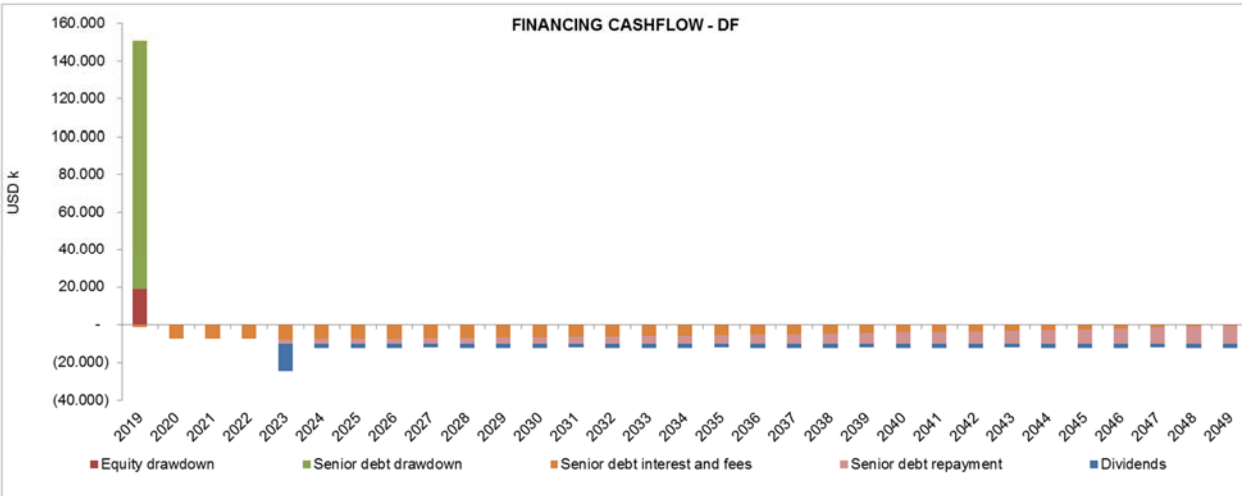
7.3.3.1 Key Results

7.3.3.1.1 Dark Fiber P3

The operating cash flow of the Dark Fiber P3 has two phases: in the first three years, the milestone payments from the PBE are received, funding 90 percent of the capital expenses in the first years. After substantial completion, the dark fiber has limited operations and maintenance expenses and receives an availability payment.



The financing cash flow of the Dark Fiber P3 starts with a senior debt and equity drawdown of $151 million in year 1 of the contract. Senior debt interest and fees start in year 2. Senior debt repayment and payout of dividends start in year 4 and add up to approximately $10 million annually until the end of the contract.



The expected milestone payments and availability payments that the Dark Fiber P3 Concessionaire needs to make its business case work are the following:

Table 20: Estimated Dark Fiber P3 Milestone Payment and Availability Payment

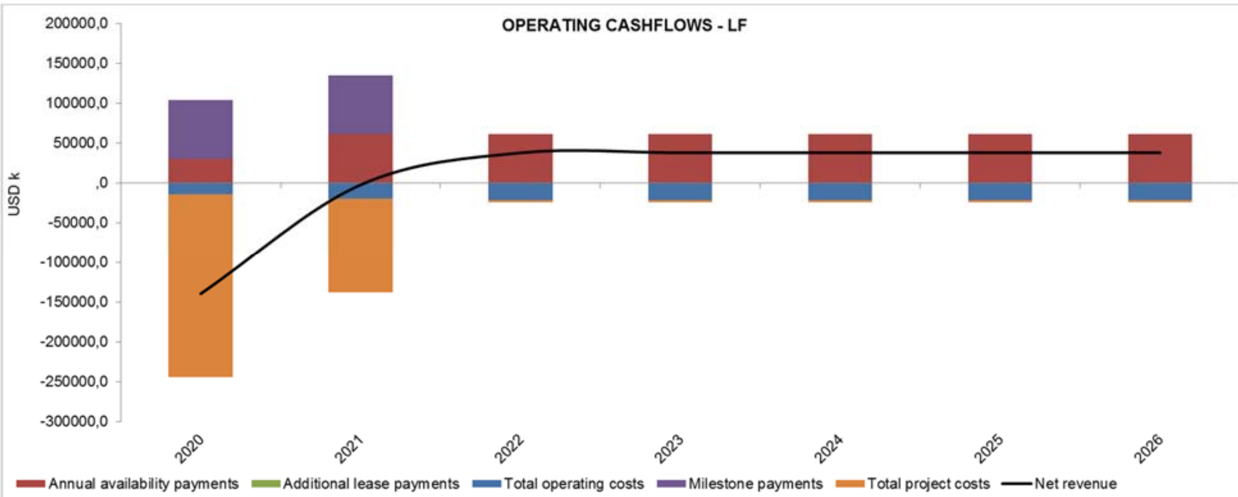
Output	Base Case	Range
Dark Fiber Milestone Payment	$1.358 billion	$1.087 billion – $1.629 billion
Dark Fiber Availability Payment	$36 million/year	$27 million/year – $45 million/year

As Table 20 illustrates, a $1.36 billion milestone payment at substantial completion (i.e., paid in years 2 and 3), in combination with annual availability payments of $36 million for 30 years, would cover all of the project costs (including the subsidy) under the base case assumptions. Because these results are uncertain (which is typical for this stage of project development), the sensitivity analysis shows the likely range of required payments, based on the main uncertainties. Under the most conservative, worst-case scenario, a milestone payment of $1.63 billion in combination with annual availability payments of $45 million would cover all of the project costs.

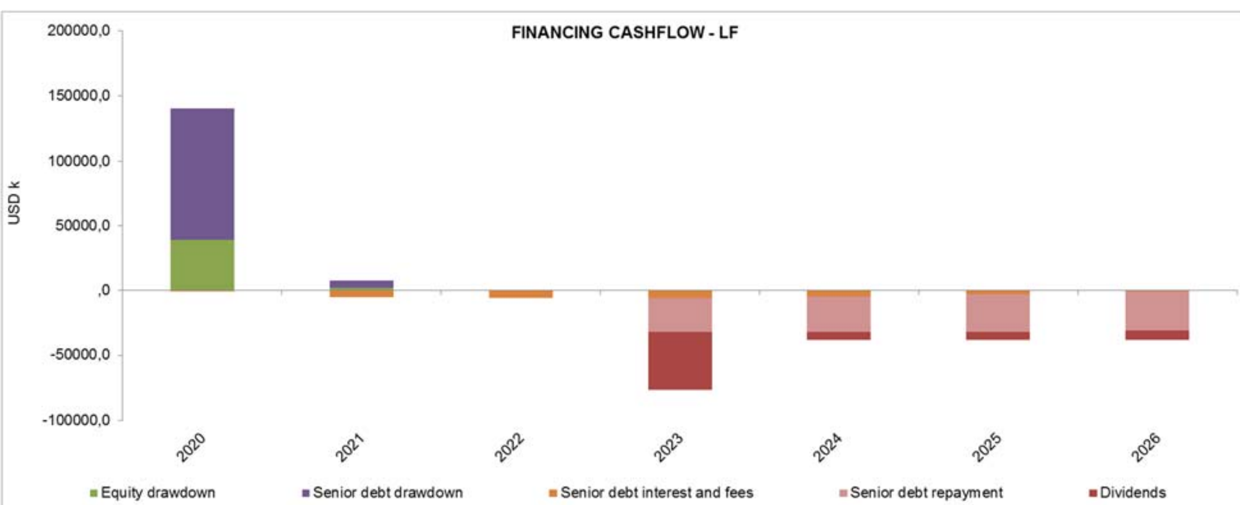
The Project Team developed the two-part payment approach (i.e., a milestone payment in combination with an availability payment) to optimize the project's financing structure. Covering all of the project costs without the milestone payment, for example, would require an annual availability payment of $129 million over 30 years under the base case scenario. Under the most conservative, worst-case scenario, the required annual availability payment would be $173 million. In both of these scenarios, the City would face significantly higher financing costs.

7.3.3.1.2 Lit Fiber P3

Operating cash flow of the Lit Fiber P3 starts in year 2 of the project. In the first two years, milestone payments are received, financing 50 percent of the capital expenditures of this P3 contract. Availability payments start in year 2, ramping up to the full $62 million in year 3, then continuing throughout the rest of the contract period. Operating costs ramp up in year 1 and 2 of the contract (year 2 and 3 of the project period) and stabilize at $21 million until the end of the contract period.



The financing cashflow of the Lit Fiber P3 is characterized by two years of drawdowns of equity and debt, with minor interest payments for senior debt, followed by five years of outflows in the form of interest, debt repayment, and dividends. In year 1 of the contract, $101 million in senior debt and $40 million in equity are drawn down to finance capital expenditures. These payments peak in year 4 of the contract at $76 million, followed by three years of combined payments of about $38 million.



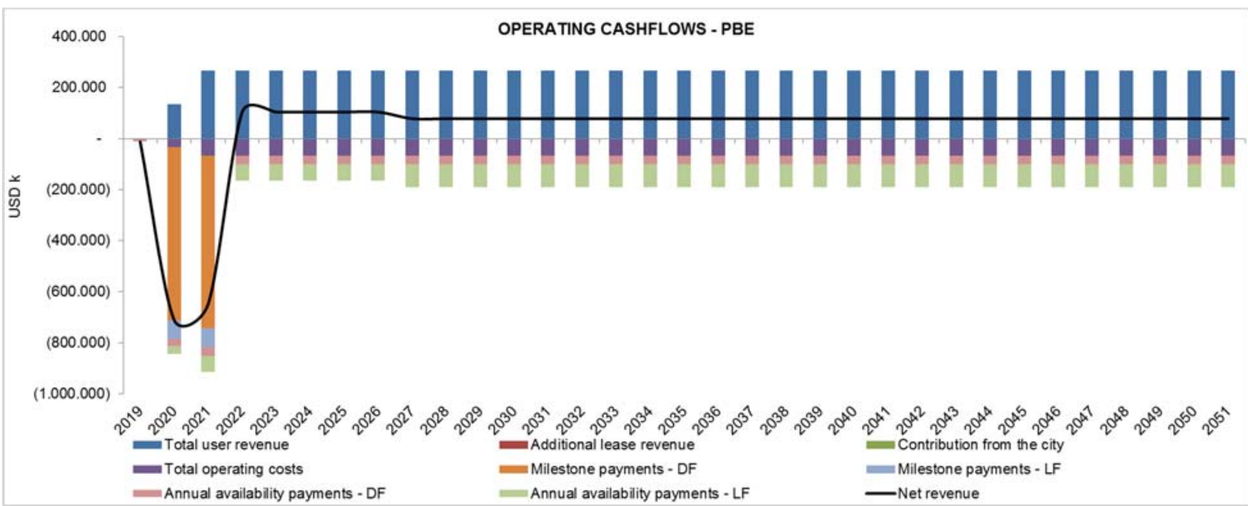
The expected milestone payments and availability payments that the Lit Fiber P3 Concessionaire needs to make its business case work are the following:

Table 21: Estimated Lit Fiber P3 Milestone Payment and Availability Payment

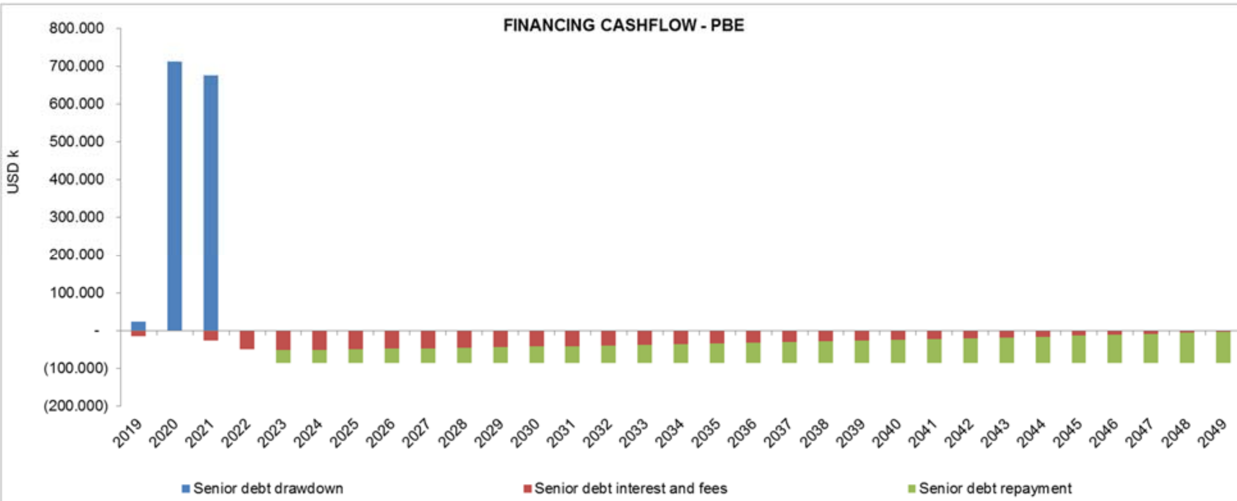
Output	Base Case	Range
Lit Fiber Milestone Payment	$147 million	$123 million – $176 million
Lit Fiber Availability Payment	$62 million/year	$42 million/year – $76 million/year

7.3.3.1.3 Public Broadband Entity

The PBE's operating cash flow is mainly defined by the revenues from Connection Fees and the payments to the two P3s. The major cash outflows are the two milestone payments to the Dark Fiber P3 in the second and third year after the start of the project. These cause net revenue to be negative until year 4 of the contract, with the most negative value reaching -$712 million in year 2. Net revenue stabilizes around $77 million per year in year 9 of the project.



PBE's financing cash flow shows major cash inflows in year 2 and 3 of the contract of $713 million and $675 million, respectively. This inflow is the senior debt drawdown that is required for the milestone payments to the P3 contracts in those years. From year 4 of the project onwards, the financing cash flow is $85 million, comprised of interest and fees for the senior debt as well as repayment of this debt facility.



The PBE needs to charge the following Connection Fees in order to make its business case work:

Table 22: Estimated Connection Fees (Base Case and Best Case)

Output	Base Case	Range
Connection Fee – residential	$51 / passing / month	$26 – $67/ passing / month
Connection Fee – business (average)	$73 / passing / month	$38 – $97/ passing / month

The range of potential Connection Fees is relatively wide, due to a series of uncertainties, as further discussed in the next section.

7.3.3.2 Sensitivity Analysis

This section provides an overview of the sensitivity analysis, reflecting the main uncertainties in the project. The indicator for which the sensitivities are shown is the residential Connection Fee, which is $51 per passing per month under the base case. Worst case is defined as the assumptions leading to a Connection Fee that is higher than under the base case assumptions; best case is defined as the assumptions leading to a lower Connection Fee than under the base case assumptions.

Table 23: Sensitivity Analysis of Dual P3 Residential Connection Fees

Variable	Sensitivity description	Worst Case Connection Fee	Best Case Connection Fee
Capex	The capital cost estimates are uncertain, due to the current stage of the project preparation and design. The variability of the cost estimates is +/- 20 percent, meaning that the worst case is 20 percent higher than the expected value (Dark Fiber high cost estimate and Lit Fiber base case cost estimate) and the best case is 20 percent lower than the expected value.	\$59	\$42
Opex	The estimates of operational and maintenance costs are uncertain, due to the current stage of the project preparation and design. The variability of the cost estimates is +/- 20 percent, meaning that the worst case is 20 percent higher than the expected value (Dark Fiber high case cost estimate and Lit Fiber base case cost estimate) and the best case is 20 percent lower than the expected value.	\$53	\$48
Lit Fiber contract term	The base case contract term for the Lit Fiber P3 concession is seven years. This is also the worst case, whereas the best case is 10 years.	\$51	\$47
Subsidy	Under the base case, low-income residents (15 percent of the total population) will pay a \$10 Connection Fee. Under a minimum subsidy scenario, low-income residents will pay a \$20 Connection Fee; under the maximum scenario, low-income residents will pay nothing.	\$52	\$49
Additional revenues	The base case does not assume any revenues from the City or any additional revenues. This is also the worst case. In the best case, the annual additional revenues are \$25 million. Note that this scenario is an illustration only; it is not based on any research and is highly uncertain. Further project preparation and the pre-procurement leasing process will reduce the uncertainty and are intended to lock in additional revenues.	\$51	\$44

Variable	Sensitivity description	Worst Case Connection Fee	Best Case Connection Fee
Financing	The financing costs are determined by a few key financing conditions. The worst case / base case / best case values for these financing conditions are as follows: ● Gearing: 85 percent / 90 percent / 91 percent ● DSCR: 1.25 / 1.20 / 1.15 ● Interest (commercial debt): 6.5 percent / 5.5 percent / 4.5 percent ● Interest (revenue bond): 4.5 percent / 3.5 percent / 2.5 percent ● ROE: 15 percent / 13 percent / 11 percent The sensitivities are calculated for the combination of minimum and maximum values.	$54	$47
All combined	This sensitivity shows the combination of all worst case assumptions and all best case assumptions combined.	$67	$26

The overall range of the residential Connection Fee is $26 to $67 for a combination of all the best case and worst case assumptions. The capex uncertainties are the most significant, followed by the financing uncertainties and the subsidy for low-income residents. Further project preparation will contribute to reducing these uncertainties.

7.4 Structuring the Lit Fiber P3 to Achieve City Goals

In the Dual P3 Model, the Lit Fiber P3 should be structured to serve the City's defined Principles and goals. Among other matters, the initiative must deliver a base level of broadband service to every San Francisco household and business; defining what that base level of service should be is the key challenge of structuring the Lit Fiber P3.[91]

In evaluating approaches to achieving the goal of delivering a base level service, we considered four options for the Lit Fiber P3 that reflect a range of costs and outcomes:

- Option 1: Lit Fiber P3 that would deliver low-level internet service to all

[91] The requirement for a base level of services is based on guidance from the City Attorney's office that use of a property-related fee for the Connection Fee requires provision of a service into every home and business. The property-related fee and other potential funding mechanisms are discussed in the appendices.

- Option 2: Lit Fiber P3 that would deliver robust, higher-speed internet service to all
- Option 3: Lit Fiber P3 that would deliver robust, higher-speed internet service to low-income residents
- Option 4: Lit Fiber P3 that would deliver universal access to a high-speed Civic Network, with internet provided not by the Lit Fiber Concessionaire but rather by ISPs

The City's goals for openness and competition are best served by Option 4—which would include robust access to a high-speed Civic Network for every household and business in the City. At the same time, the Lit Fiber Concessionaire would provide wholesale access to competing ISPs that would make possible robust competition with very low start-up costs for ISPs that choose to provide retail services over the network lit up by the Lit Fiber Concessionaire. This approach is new and untested in a U.S. city the size of San Francisco, but has the potential to achieve the City's key goals (including equity, competition, civic opportunity, and innovation) while avoiding some of the significant pitfalls and financial failings of the other approaches.

In the sections below, we describe the pros and cons of each option, and the analysis that led to our recommendation.

7.4.1 Option 1: Low-Level Internet Service to All

The first option we considered would require the Lit Fiber Concessionaire to deliver a low-level internet service (i.e., at a level lower than BLA's recommended 25 Mbps downstream, 3 Mbps upstream) to every home and business in the City. Achieving equity through ubiquity, this approach makes a direct connection between the Connection Fee and service; every property owner would pay a fee, and every household and business would receive service.

This approach presents two benefits in terms of the City's goals for market-based competition. First, the lit network would serve as a platform for the Lit Fiber Concessionaire to sell wholesale services to competing retail ISPs. Second, because a low-level internet service would be slower than many higher-income residents' current services, it would be unlikely to satisfy those users and thus would be unlikely to take significant market share from the competing ISPs.

Those competitive benefits, however, are largely overshadowed by several negative aspects of delivering a low-level internet service to every home and business. First, given the high cost of deploying the proposed broadband infrastructure, this option would be an expensive mechanism for delivering a largely inconsequential service for many residents. Second, many of the lower income residents who might benefit from this service may already be eligible for low-cost, low-bandwidth programs such as Comcast's Internet Essentials program—so this option would duplicate an existing service. Finally, because the service would be low-level, it would not deliver the transformative benefits of "true" broadband to the very citizens, those of lower-income, that the Fiber for San Francisco Initiative is designed to support.

7.4.2 Option 2: Robust High-Speed Internet Service to All

Recognizing that the low-level service considered in Option 1 would not deliver the benefits of true broadband to the City's low-income residents, we next considered delivering robust internet service to every home and business. In this scenario, the Lit Fiber Concessionaire would serve each resident and business with at least 25/3 service, the level of service recommended by the Budget and Legislative Analyst and that meets the FCC's definition of broadband.

Like Option 1, this option would deliver a service to every resident and business—achieving equity and making the case for a property-related fee. By increasing the minimum speed of the base-level service, this option would provide "true" broadband to low-income residents. The base-level service would be an improvement over Comcast's and AT&T's low-cost, low-bandwidth programs, rather than a duplication.

But delivering robust internet service to every resident and business would have negative consequences for the competitive market. Because it would be robust, this base-level service would likely satisfy many users—who would then be unlikely to pay for higher-level service from the competing ISPs that lease access on the platform lit by the Lit Fiber Concessionaire. By eroding the potential market for ISPs, this option would dramatically change the economic prospects for the network.

7.4.3 Option 3: Robust, High-Speed Internet Service to Low-Income Residents

In our analysis of Option 2, we found that providing a robust internet service to all passings would achieve equity in terms of the benefits of true broadband, but would make much more challenging the project's potential to enable new competition and generate related income. Drawing a distinction between residents who can afford to buy robust broadband and those who cannot, we then looked at the effects of delivering robust internet as a base-level service only to low-income residents. Higher-income residents and business passings would pay the Connection Fee but would not receive a base-level service.

This option ameliorates some of the shortcomings of Option 1 and Option 2. Most importantly, in terms of equity, lower-income residents would receive the kind of high-bandwidth broadband service that is prioritized by the Fiber for San Francisco Initiative, and the benefits that come with that level of service. And in terms of the business model, the potential market for competing retail ISPs would not be diminished, because higher-income residents would not be receiving a service. That said, Option 3 has some significant shortcomings. Like Option 1, it would represent an extremely expensive means of delivering service to lower-income residents. And because higher-income residents and businesses would not be receiving any base-level service, the sources of funding for the Connection Fee might be reduced because not all payers of the Fee are receiving a direct service.

7.4.4 Option 4: Robust Civic Network Service to All

In our P3 analysis, we determined that separating the network layers (dark fiber infrastructure in one P3, lit service in another) would solve some of the fundamental issues in terms of the Fiber for San Francisco Initiative's risk profiles and financial projections. Similarly, this option solves the puzzle of providing a base-level service by treating infrastructure and internet service as separate issues.

In this option, as in the first three options above, a Dark Fiber Concessionaire would construct infrastructure to pass every residence and business in the City. A Lit Fiber Concessionaire would light the fiber and sell wholesale access to competing ISPs.

Where this option diverges from those other approaches is in the definition of the base-level service. Rather than choosing an internet service level, this option envisions delivering 1 Gbps *intranet* access to every home and business and thereby creating a Civic Network that would connect all San Francisco residents and businesses to civic, educational, health care, and non-profit resources. Residents and businesses can also choose to purchase retail services (from competing providers that would buy wholesale service from the Lit Fiber Concessionaire), in addition to the free, high-bandwidth access to the Civic Network.

To address the issues of affordability and equity, the City could provide a subsidy to low-income residents to purchase retail internet service—though we note that service fees may be very low under this scenario because the technical configuration would make it easy and cheap for many retail service providers to compete over the network.

This option checks the boxes on both the City's priorities and the primary benefits achieved in the other options. It would ensure ubiquitous access and, thus, would deliver value for the Connection Fee. It would also make the dark fiber infrastructure a platform the Lit Fiber Concessionaire to sell wholesale services to competing retail service providers—and would maintain the market for those providers.

7.4.5 Technical Description of the Potential Civic Network

In the Option 4 scenario, the Lit Fiber Concessionaire would design and operate a Civic Network which will be made available at no extra charge to subscribers connected to the City's FTTP network.[92] This service will provide access to certain resources to be made available by the City as well as a self-service portal, to be operated by the Lit Fiber Concessionaire, which will allow

[92] A detailed technical description of the functioning of the Civic Network and the potential to enable robust open access and competition over the network is included in the appendices to this report.

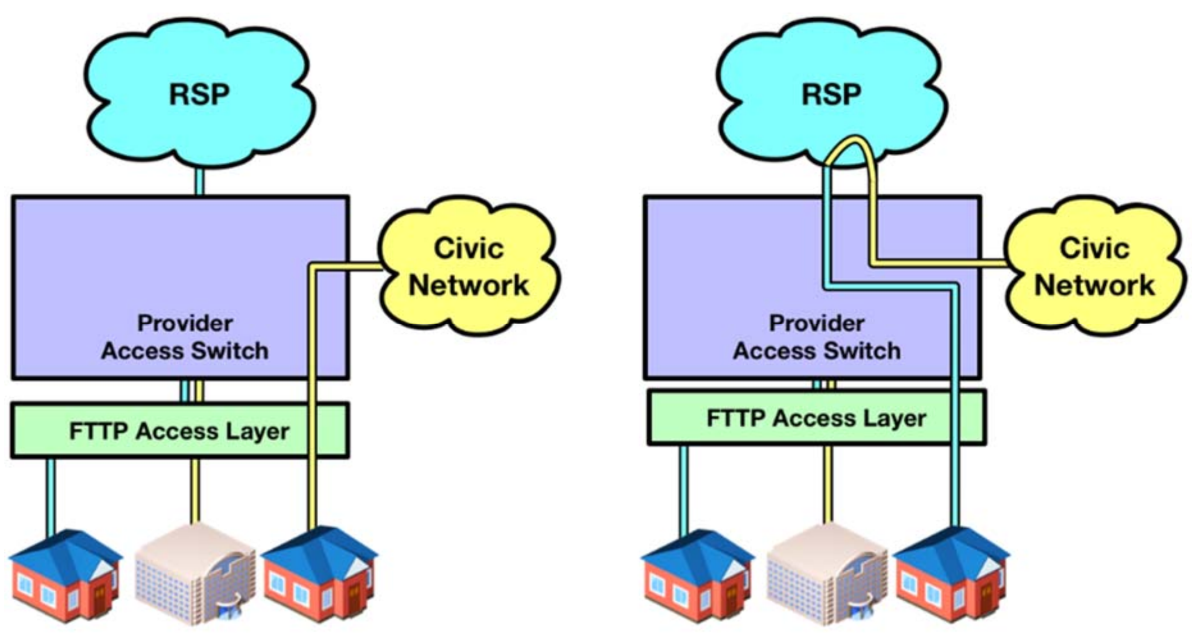
subscribers to sign up for services offered by RSPs. Access to the City's Civic Network should be provisioned to a subscriber port via an EVC in the same way that retail services are provisioned.

The self-service portal will act as a virtual storefront for services being offered on the City FTTP network. The Lit Fiber Concessionaire will be responsible for developing and operating a backend service which will allow RSPs to list their available services and pricing and a frontend service which will allow subscribers to select those services. Depending on the service requested, the portal should either trigger an automated process which will provision the requested service to the subscriber port and alert the RSP to being billing, or should automatically create a service request which will be sent to the Lit Fiber Concessionaire NOC and the RSP so provisioning and billing services and be performed by the respective entities.

The City's Civic Network will be made available to all subscribers on the FTTP network regardless of whether they subscribe to retail services. Because different EVCs on the network are separated, with traffic for each EVC being routed by each RSP or the Civic Network, a subscriber receiving two or more service EVCs would need to have each service delivered on a separate physical port or on different VLANs over the same port. This may be a reasonable situation for subscribers who run their own business-class routers and switches, but would be too complex for most residential subscribers and many business subscribers.

In order to provide easy access to the City's Civic Network for subscribers who also subscribe to a retail service, the agreement with RSPs should require a no-cost interconnection with the City's Civic Network. This will allow subscriber traffic destined for the City's Civic Network to be routed over the RSP's network. (See Figure 15.)

Figure 15: FTTP Subscribers Can Access Civic Network Directly or via an RSP's Network



8 Single Dark Fiber P3 Approach

This option envisions a markedly different approach to the entire Fiber for San Francisco Initiative. In contrast to the Dual P3 Model, in this alternative approach the City would enter into a single P3 for dark fiber only (Single Dark Fiber P3) and play no financial or operational role in how the fiber is lit or services provided over it. Rather, the City would focus its efforts on enabling competition at the dark fiber layer. It would execute a Dark Fiber concession and the Public Broadband Enterprise or the Concessionaire would then lease dark fiber on a wholesale access to competing ISPs. The ISPs would light the fiber and sell retail services to any interested residents or businesses.

8.1 Benefits

So long as a market emerges for dark fiber leases that would enable new competition, a Single Dark Fiber P3 Model offers greater simplicity, lower cost, and—potentially—reduced controversy.

8.1.1 Reduced Complexity and Cost

With a Single Dark Fiber P3, the City would spend dramatically less because it would not take on the financial commitment necessary for a Lit Fiber Concession. As the financial analysis for the Dual P3 Model demonstrates, the Connection Fee for the Lit Fiber P3 is considerable.[93] If that component is removed and the Connection Fee is limited to the Dark Fiber P3 only, the revenue necessary to support the model is greatly reduced.

Developing a Single Dark Fiber P3 only also reduces complexity and administrative burden for the City. Unlike lit services and equipment, dark fiber is a stable, predictable asset. It is an infinitely scalable, long life, future-proof asset that will continue to be usable and useful over 30 years or more so long as it is adequately maintained. And fiber is universally acknowledged as the most robust and most scalable of communications media, enabling scaling as necessary as bandwidth needs grow and essential to support future generations of wireless technology, both mobile and fixed. Lit services, in contrast, change dramatically over time, in response to market changes and service innovations. And the equipment to light up those services will also change as the market and bandwidth demands grow. Broadband equipment must also be replaced, depending on the component, approximately every seven to 10 years. Administering and enforcing a Lit Fiber P3 with all these elements is an administrative challenge that is alleviated by eliminating the Lit Fiber P3 entirely and leaving all these elements to the market.

The model also removes from the City's purview network operations, where a considerable amount of risk lies in managing technological and customer service aspects of the network. Rather than determining parameters and terms for these areas of operation through the Lit Fiber

[93] The Connection Fee analysis is detailed in Section 7.

PG, the City's role would be limited to the simpler dark fiber layer of the network. The Concessionaire also would have a role limited to building and maintaining dark fiber, and there would be no need for a Concessionaire to deal with the more challenging areas of network performance, service delivery, and customer relationships.

8.1.2 Removes the City from the internet business or competing with private companies

The Single Dark Fiber P3 Model also potentially reduces the challenges inherent in the City's work to promote competition and better broadband. Regardless of merits, City efforts to expand broadband and broadband competition have been aggressively opposed by incumbent phone and cable companies nationwide. In a dark fiber model, the City (and its Concessionaire) play no role in providing services to the public, but rather provide a dark fiber platform to enable the private sector to enter the service business. Frankly, incumbents are likely to oppose this initiative regardless of how limited the City's role is, but the customary incumbent claim of "unfair competition" from the public sector is undercut by the model.

Further, by removing the City from any role in shaping services, pricing, or performance standards, the Single Dark Fiber P3 preserves the full retail market for competing ISPs—rather than using a P3 to deliver some level of services to the public.

8.2 Challenges

Though simple and efficient, the Single Dark Fiber P3 Model reduces options with regard to funding and to competition.

8.2.1 Funding options

This approach potentially reduces the range of options before the City for funding. In particular, without a service delivered to every home and business, a property-related fee cannot be used for the Connection Fee to fund the project.[94] Eliminating the Lit Fiber P3 is efficient, but narrows the City's path forward.

8.2.2 Competition considerations

The competition considerations are complex with respect to comparison between the Single Dark Fiber P3 and the Dual P3 models. While the Single Dark Fiber P3 creates unprecedented opportunity at the dark fiber layer, it also does not deliver competition as effectively as a Lit Fiber 3 potentially can.

Though access to dark fiber greatly reduces the barrier to entering the San Francisco market for new providers, there is still considerable cost and complexity in lighting and operating an optical network over dark fiber. Only a sophisticated, well-funded company will have the scale and

[94] A range of potential funding sources is analyzed in the appendices to this report.

capacity to do so. Given the cost involved and the potential competition in the market created by the dark fiber itself, it's not likely that more than a small handful of entities would be interested in leasing dark fiber in the near term. Indeed, the market, depending on how the fiber is priced, may support only one or two lessees for the foreseeable future. Over the long term, however, market demand and structures may change and new opportunities for dark fiber competition may arise.[95]

In contrast, a lit network can provide very inexpensive open access to many service providers, including very small operations with modest resources, at low incremental cost.[96] Lighting the network in the first place is costly, but the platform can then add additional competing providers quickly and cheaply.

The unknowns regarding the dark fiber market also raise the question of whether the model will ensure sufficient competition emerge to support the City's affordability and digital equity goals. In this scenario, the City would not be able to use the Lit Fiber P3 to itself provide lower cost products for low-income residents. Rather, the City could provide a subsidy to low-income residents to ensure they can afford retail services.

8.3 Financial Analysis

To understand the potential Connection Fee necessary to support the Single Dark Fiber P3 Model, the Project Team developed a version of the financial model for dark fiber only. The model suggests that the necessary Connection Fee, assuming no dark fiber revenues, will be in the range of $15 to $37 per residential passing per month, with a base case value of $28. The average business Connection Fee would be in the range of $21 to $54 per passing per month, with a base case value of $41. See Table 24.

Table 24: Estimated Single Dark Fiber P3 Connection Fees (Assuming No Additional Revenue)

Output	Base Case	Range
Connection Fee – residential	$28 / passing / month	$15 – $37 / passing / month
Connection Fee – business (average)	$41 / passing / month	$21 – $54 / passing / month

The Project Team next modeled a range of scenarios to understand how dark fiber revenues may reduce the necessary residential Connection Fee. Given that a dark fiber market of this type

[95] In Huntsville, Alabama, where the city's municipal utility owns a fiber network with this business model, Google Fiber has thus far been the only entity to lease fiber from the utility, even though others may can lease based on Huntsville Utilities' established rates. Over time, there will potentially be other ISP users of the city's fiber, particularly to serve larger businesses and institutions, though we question whether the economics exist for another provider to compete against Google Fiber in the residential market, as least in the short-term.

[96] The technical description for low cost open access over a lit network can be found in Section 7.

(connecting every home and business) has never been attempted in a city of the size of San Francisco, we analyzed data from two other projects in smaller cities where this model has been pioneered to understand the financial implications for San Francisco of the revenues generated in those cities.

The City of Westminster, Maryland, for example, has a 20-year contract with Ting Internet in which the city is obligated to finance and build all of the outside plant (including drops to customers' premises). Ting is leasing fiber with a two-tiered lease payment. One monthly fee is based on the number of premises the fiber passes ($6 per month per passing); the second fee is based on the number of subscribers Ting enrolls ($17 per month per subscriber).[97]

In another variation on this model, Huntsville, Alabama's municipal electric utility is building a fiber network and Google Fiber is leasing fiber throughout the city to serve residences and small businesses.[98] Google Fiber's lease is for 20 years based on a rate sheet that provides for various levels of pricing based on amounts and volume. The pricing structure is complex but we estimate Google Fiber's monthly cost to be approximately $6 to $7 per month per passing.[99]

The financial model suggests that applying the Westminster and Huntsville pricing to San Francisco would bring the expected Connection Fee down from $28 per month without dark fiber revenues to $20 to $26 per month, respectively.

The following sensitivity analysis reflects the main uncertainties in the project. The indicator for which the sensitivities are shown is the residential Connection Fee, which is $28 per passing per month under the scenario without any additional fees. Worst case is defined as the assumptions leading to a Connection Fee that is higher than under the base case assumptions; best case is

[97] Because Ting will pay Westminster a monthly fee of $6 for every home and business passed, Ting is financially obligated to the city from day one, even if it has no customers. This structure gives the city confidence that Ting is highly incented to sell services to cover costs. Ting will also pay the city $17 per month for each customer it serves. In later years, when Ting's revenue hits certain thresholds, Ting will pay the city a small fraction of its revenue per user. That mechanism is designed to allow the city to share in some of the upside of the network's success. In other words, the city will receive a bit of entrepreneurial reward based on the entrepreneurial risk the city is taking. Perhaps most significantly, there is also a mechanism built into the contract that ensures that the two parties are truly sharing risk around the financing of the outside plant infrastructure. In any quarter in which Ting's financial obligations to the city are insufficient to meet the city's debt service, Ting will pay the city 50 percent of the shortfall. In subsequent quarters, if Ting's fees to the city exceed the debt service requirements, Ting will be reimbursed an equivalent amount. This element of the financial relationship made the deal much more attractive to the city because it is a clear demonstration of the fact that its private partner is invested with it.

[98] Huntsville is not financing or building the drops to the home; it's obligation to Google is to provide fiber that passes the premises only.

[99] In contrast, Ting's obligations to Westminster are based in part on how much fiber it uses and in part on how many customers it secures and revenues it generates. As a result, Westminster will have less predictability and certainty about its revenues from Ting, but has the potential to share in upside in the event that Ting is very successful in that market.

defined as the assumptions leading to a lower Connection Fee than under the base case assumptions.

Table 25: Sensitivity Analysis of Single Dark Fiber P3 Residential Connection Fees

Variable	Sensitivity Description	Worst Case Connection Fee	Best Case Connection Fee
Capex	The capital cost estimates are uncertain, due to the current stage of the project preparation and design. The variability of the cost estimates is +/- 20 percent, meaning that the worst case is 20 percent higher than the expected value (Dark Fiber high cost estimate) and the best case is 20 percent lower than the expected value.	$32	$24
Opex	The estimates of operational and maintenance costs are uncertain, due to the current stage of the project preparation and design. The variability of the cost estimates is +/- 20 percent, meaning that the worst case is 20 percent higher than the expected value (Dark Fiber high case cost estimate) and the best case is 20 percent lower than the expected value.	$29	$27
Subsidy	Under the base case, low-income residents (15 percent of the total population) will pay a $10 Connection Fee, and those who buy internet service (expected to be 80 percent of the low-income residents) receive an additional $30 subsidy per month. Under a minimum subsidy scenario, low-income residents will pay a $20 Connection Fee and the additional internet service subsidy is $20; under the maximum scenario, low-income residents will pay nothing and the additional internet service subsidy is $40.	$29	$27
Additional revenues	The base case does not assume any revenues from the City or any additional revenues. This is also the worst case. In the best case, the annual additional	$28	$22

Variable	Sensitivity Description	Worst Case Connection Fee	Best Case Connection Fee
	revenues are $25 million. Note that this scenario is an illustration only; it is not based on any research and is highly uncertain. Further project preparation and the pre-procurement auction will reduce the uncertainty and are intended to lock in additional revenues.		
Financing	The financing costs are determined by a few key financing conditions. The worst case / base case / best case values for these financing conditions are as follows: • Gearing: 85 percent / 90 percent / 91 percent • DSCR: 1.25 / 1.20 / 1.15 • Interest (commercial debt): 6.5 percent / 5.5 percent / 4.5 percent • Interest (revenue bond): 4.5 percent / 3.5 percent / 2.5 percent • ROE: 15 percent / 13 percent / 11 percent The sensitivities are calculated for the combination of minimum and maximum values.	$31	$26
All combined	This sensitivity shows the combination of all worst case assumptions and all best case assumptions combined.	$37	$15

The residential Connection Fee in the Single Dark Fiber P3 Model is $20 per month under a scenario assuming a monthly per passing fee of $6 and a monthly per subscriber fee of $6 (at a take rate of 50 percent for residential customers and 30 percent for business customers) in addition to the Connection Fee. The table below shows the main sensitivities under this scenario.

Table 26: Sensitivity Analysis of Single Dark Fiber P3 Residential Connection Fees with Additional Fees

Variable	Sensitivity Description	Worst Case Connection Fee	Best Case Connection Fee
Capex	The capital cost estimates are uncertain, due to the current stage of the project preparation and design. The variability of the cost estimates is +/- 20 percent, meaning that the worst case is 20 percent higher than the expected value (Dark Fiber high cost estimate) and the best case is 20 percent lower than the expected value.	$24	$16
Opex	The estimates of operational and maintenance costs are uncertain, due to the current stage of the project preparation and design. The variability of the cost estimates is +/- 20 percent, meaning that the worst case is 20 percent higher than the expected value (Dark Fiber high case cost estimate) and the best case is 20 percent lower than the expected value.	$21	$19
Subsidy	Under the base case, low-income residents (15 percent of the total population) will pay a $10 Connection Fee, and those who buy internet service (expected to be 80 percent of the low-income residents) receive an additional $30 subsidy per month. Under a minimum subsidy scenario, low-income residents will pay a $20 Connection Fee and the additional internet service subsidy is $20; under the maximum scenario, low-income residents will pay nothing and the additional internet service subsidy is $40.	$21	$19
Additional revenues	The base case does not assume any revenues from the City or any additional revenues. This is also the worst case. In the best case, the annual additional revenues are $25 million. Note that this scenario is an illustration; it is not based on any research and is highly uncertain. Further project preparation and	$20	$14

Variable	Sensitivity Description	Worst Case Connection Fee	Best Case Connection Fee
	the pre-procurement auction will reduce the uncertainty and are intended to lock in additional revenues.		
Financing	The financing costs are determined by a few key financing conditions. The worst case / base case / best case values for these financing conditions are as follows: • Gearing: 85 percent / 90 percent / 91 percent • DSCR: 1.25 / 1.25 / 1.15 • Interest (commercial debt): 6.5 percent / 5.5 percent / 4.5 percent • Interest (revenue bond): 4.5 percent / 3.5 percent / 2.5 percent • ROE: 15 percent / 13 percent / 11 percent The sensitivities are calculated for the combination of minimum and maximum values.	\$22	\$18
Take rate	In the base case, a take rate of 50 percent for residential customers and 30 percent for business customers is assumed. In the best case assumption, the take rate is increased to 60 percent (residential) and 40 percent (business customers). In the worst case assumption, the take rate is reduced to 30 percent (residential) and 20 percent (business customers).	\$21	\$19
All combined	This sensitivity shows the combination of all worst case assumptions and all best case assumptions combined.	\$30	\$6

The sensitivity analysis demonstrates that a good structuring of the per passing and per customer fees in combination with upfront commitment of additional revenues can help reduce the Connection Fee significantly.

9 Recommendations for Implementation and Procurement Strategy

This section of the report concerns the procurement strategy for the recommended approach for the Fiber for San Francisco Initiative. In summary, this section describes the ways in which this pioneering FTTP P3 procurement will be the first of its kind and that, given its uniqueness and pioneering nature, a procurement strategy customized for application of P3 delivery mechanisms to the new P3 area of FTTP is necessary.

We therefore suggest a procurement process grounded in the traditional P3 process but customized and expanded to account for the unique aspects of this effort, including (1) funding authorization requirements, (2) unique market characteristics, and (3) the lack of familiarity of the investment community with P3s in the broadband sector.

We recommend the following steps in the procurement process:

1. **Industry Sounding**. A pre-procurement industry sounding to clarify and market the project and proposed P3 structure to generate market appetite as well as solicit inputs to further refine the structure. The industry sounding could include a full day event or one-on-one conversations.

2. **Pre-Procurement Dark Fiber Leasing**. A pre-procurement pre-lease or sale of dark fiber and other network capacity in advance of the P3 RFPs so as to quantify and secure some revenues that would otherwise be speculative; this will enable (1) bids with lower requirements for City funding/guarantees, and (2) a more competitive bidding process in which all bidders can account for these revenue streams.

3. **P3 Procurement.** In the event that the Dual P3 Model is adopted, a P3 procurement process that distinguishes two procurements: one for dark fiber and other outside plant infrastructure (Dark Fiber RFP); and a separate one for the service provider (Lit Fiber RFP), to be run partially in parallel.

4. **Integration of RFP Development and Industry Consultation/Negotiations.** Although the City has been contemplating an RFP development process followed by negotiations with one or more selected bidders, we recommend integrating these phases and building consultation with selected bidders into a more extensive process of RFP development and vetting. This process—which should be more extensive than in other P3 sectors, given the novelty of this effort—will enable the necessary level of interaction with potential bidders, giving the City opportunity to refine these complex procurements, while enabling the bidders to further understand and craft bids for this new, unfamiliar asset class.

Overall, the procurement process should:

- **Begin as early as possible in order to gather industry feedback before seeking funding approval.** A key task for this project is to ensure a match between the level of funding approved and what bidders will propose during the procurement process. In an ideal situation, bidders would be selected and a firm understanding of the level of financial commitment needed would be clear before funding authorization is sought. However, bidders tend to require funding approval in advance of submitting complex bids and are less willing to put significant effort into completing bids for projects that they have reason to doubt will be funded. Therefore, starting engagement with potential bidders through an industry sounding, and initiating the RFQ and RFP process as early as possible in order to obtain some level of interaction and information from bidders, will help provide some clarity to the approval process and provide decision-makers with as much information as is feasible at that stage of the process, even if binding bids have not already been submitted.

- **Build in sufficient time and flexibility.** A procurement timeline that accounts for the pioneering and singular nature of this effort and thus builds in sufficient time and flexibility to vet all elements of the bid requirements; an extended timeline will likely also be required by the emerging strategy of separating the Dark Fiber RFP from the Lit Fiber RFP.

- **Apply P3 procurement best practices.** Even though this procurement will be the first-of-its-kind, several P3 procurement best practices can be applied, including:

    - **Shortlist three or four qualified bidders (RFQ Phase)**: Given the time and resources required for the City and bidders, it is important that the City selectively identify bidders for advancement. The shortlisting of qualified bidders is considered standard practice for any complex procurement and is particularly important for P3 procurements. Only having a small group of pre-qualified bidders allows the City to focus its resources on responding to a smaller number of bidders. From the bidders' perspective, because the cost of developing a detailed proposal during the RFP stage is significant, they too prefer to compete among a handful of shortlisted teams. A smaller pool of competitors increases the probability of succeeding at the RFP stage, which motivates bidders to invest resources in developing a high-quality bid.

    - **Communicate with the bidders prior to bid submission (Draft RFP Phase):** The City can use a multi-stage "draft RFP" process to increase dialogue with the potential P3 concessionaires, with the objective of crafting an agreement that adequately reflects acceptable long-term transfer of risks and responsibilities between the parties in the most efficient way possible. When done well, a draft RFP process is an organized way to solicit input from pre-qualified bidders and increase fair competition. A draft P3 agreement can be included in the draft RFP documents to gain early industry input on the proposed contractual agreement, and to limit negotiations with a single preferred bidder. This process decreases the likelihood of major last-minute amendments to the final RFP, which could distort the competitive process and increase transaction costs. Ideally, it also replaces the post-bid negotiations with one or more selected bidders that are contemplated by the City's original plan. Given the pioneering nature of this effort and the newness of this sector to P3 bidders, multiple iterations of this draft RFP process may be advisable, and the timeline should reflect the need for flexibility and creativity during the RFP development process.

These issues are discussed in further detail below.

9.1 A Pre-Procurement Capacity Leasing Process Should Precede the P3 Procurement so as to Improve P3 Bidding Outcomes by Accounting for Some New Revenue Opportunity

One way to demonstrate the potential viability of the opportunity in advance of a full funding decision, both to policy-makers and to potential bidders, relates to the second primary consideration of procurement for this initiative—that is, the nature of the infrastructure and services at hand.

9.1.1 FTTP Represents an Untested Area for P3 Delivery, in a Complex and Ever-Changing Sector

Unlike traditional P3 areas, broadband and FTTP exist in a somewhat "competitive" market (although it is a market of uneven levels of service to various parts of the City, and with services less capable and less robust than the FTTP infrastructure envisioned by this initiative). In addition, the use of the fiber and the ways in which connectivity and the internet will be used over the course of the life of this network are in substantial ways unpredictable.

Unlike a water utility P3 that will, in its first year and its last year, provide water—or a toll road that will throughout the life of the concession provide access to a navigable road—the FTTP network will be used in the medium and long term in ways that are largely impossible to project at the current moment. Generally, we can anticipate only some of the uses of the network—out to perhaps seven to 10 years. Consider, for example, that the advent of the commercial internet was only 22 years ago. Facebook was founded only 13 years ago. Netflix started offering streaming content only 10 years ago.

As a result, it is not only difficult to determine how consumers will use this infrastructure and services over it in the future, but it is also extremely challenging to anticipate what companies will be interested in with respect to the use of the City's new infrastructure.

9.1.2 The Opportunity Presented by This Initiative Is Unfamiliar to the Investment Community

In addition, the opportunity the City is about to present to the private sector is unprecedented. There has never before existed in any American community an opportunity for a private entity to lease fiber or broadband infrastructure to reach 100 percent of the homes and businesses in the community. While a handful of localities have sought to offer open-access networks, those were on a smaller scale than San Francisco and only connected a portion of the community (those customers that paid for service) and, even then, generally over networks without the technical robustness of what is contemplated for this initiative. In contrast, what the City has elected to examine for this initiative is immediate connectivity to 100 percent of the homes and businesses in the community.

In addition, there has never before existed a mechanism for companies to lease dark fiber on such a scale. Because the phone and cable incumbents do not allow access to their distribution networks to the home and business at the dark fiber layer (and, indeed, at any layer in many cases), private sector internet entrepreneurs and other companies have never had the opportunity presented here.

For all these reasons, it is deeply challenging to anticipate the kinds of lessees that may emerge even in the first few years after the network is built, let alone in the medium and long term.

In sum, the opportunity the City is presenting to the private sector is unprecedented, and therefore there exist no empirical data by which to project or understand what kinds of potential revenues may emerge. In addition, P3 investors will not accept the kind of uncertainty that is a necessary element of the pioneering nature of the asset. Rather, they will bid with a requirement that the risk presented by this uncertainty is borne by the City.

9.1.3 A Pre-Procurement Lease of Access to the Network Would Help to Mitigate These Uncertainties

Given the confluence of all these factors, we recommend a substantial additional phase to this P3 procurement—one that would occur in advance of an RFP for a P3 bidder. This first procurement would be aimed not at the P3 investment community, but at the potential users of the network, who would be interested in leasing capacity on the network to reach residences and businesses in San Francisco.

The procurement would be designed to quantify at least some of the potential dark fiber leasing revenues and to effectively create binding mechanisms and revenue streams from these bidders that would then become part of the RFP and the business proposition offered to the P3 bidders.

In other words, a preliminary procurement of anchor customers would allow the City's P3 procurement to quantify and guarantee a substantial source of revenue to the bidders—which would reduce the required financial contribution to be asked of the taxpayers.

Outside the P3 context, this kind of strategy has been used on a much smaller scale in a few communities that have "pre-sold" dark fiber leases before construction so as to bring in revenues. The City could entice dark fiber lessees by offering pre-construction pricing akin to the real estate environment, and in this way, could convert at least some of the network's revenue potential from speculative to guaranteed.

A further benefit of this strategy arises from the fact that identifying and securing these revenues in advance of a P3 procurement will result in a more competitive procurement, as all the bidders will be able to build in to their business models these potential revenues. In contrast, if these revenues are still speculative, a single bidder may be able to quietly enter into an agreement with a potential lessee of fiber; this would skew the competitive process because other bidders would not be able to factor those revenues into their bids, even though those revenues are likely to materialize.

The combination of all these factors leads us to recommend a procurement process that includes contingent dark fiber leasing in advance of the P3 procurement.

9.1.4 A Pre-Procurement Industry Sounding Should Be Used to Market the Project and Solicit Inputs from the Private Sector

Due to the unique nature of this project, including an ambitious project scope, competitive market landscape, and potentially, a dual P3 structure, an industry engagement event ("industry sounding") is highly recommended. Industry sounding is used as a forum for providing information about the project to potential bidders, marketing the project, and soliciting input from bidders.

9.2 The Procurement Timeline Should Be Developed in Light of the Complexities and Newness of the Strategy

The procurement timeline should account for the pioneering and singular nature of this effort and build in sufficient time and flexibility to vet and negotiate various elements of the bid requirements. We urge the City to build a prudent and risk-mitigating procurement timeline so as to enable multiple stages of vetting of various elements of the bid documentation with potential bidders, as well as expert comment on the effort.

The newness and innovative nature of the City's combination of technical scope (open, ubiquitous FTTP) and delivery mechanism (P3) creates uncertainty and risk that can to some extent be mitigated by a very organized, fair, and transparent procurement process that strives to limit one-on-one negotiations with a single bidder as much as possible. Therefore, we recommend a process that has been used in P3 procurements globally, and has emerged as a best practice. This process features a detailed request for qualifications (RFQ) process in which bidders are shortlisted, and a draft RFP and final RFP process that allows for dialogue between the City and shortlisted bidders—resulting in robust competition amongst a small number of qualified bidders on a final RFP and P3 contract that does not necessitate extensive negotiations after selection of preferred bidder.

In a pioneering area such as FTTP, using this recognized P3 process could reduce uncertainty and allow for refinement and change of strategies or terms that can enhance value-for-money for the City, and produce fair, and transparent competition.

The need for time is also required by the potential Dual P3 structure of separating the RFP for the fiber network from the RFP for operations and service. As part of this emerging strategy, there are two options for how to organize the dark fiber procurement, and the lit services procurement: (1) sequential procurements, or (2) staggered procurements. The first option is for the procurement of the P3s to be done sequentially, first for the dark fiber, and then for the services P3. This option is more in line with the timing of the project overall and holds fewer procurement risks related to possible gaming of the process, and challenges.

The second option is for the procurement of the P3s to be completed in a staggered manner, such that the procurement of the Dark Fiber P3 begins, and only closes after the Lit Fiber P3 procurement begins. This staggered procurement allows for the City to use the draft RFP process within both P3 procurements to work through coordination issues between the two inter-related projects. This enables the City to guard against locking itself into a Dark Fiber P3 contract that may not be optimal for the subsequent Lit Fiber P3. This staggered approach can also provide a better indication of the funding requirements to the City, as information from both procurements can be used to provide a firm indication of financial need from the entire, integrated project.

As such, although it will be more complicated to use a staggered procurement approach, we recommend that the City use the staggered approach into order to address coordination issues within the two competitive procurement processes.

9.3 The P3 Procurement Process Should Begin as Early as Possible in Order to Gain Inputs from Bidders Prior to Putting Together the Proposed Funding Authorization

Funding authorization requirements and market viability necessitate a relatively extensive timeline to prepare the procurement and educate policy-makers and the public regarding the project.

9.3.1 The P3 Procurements Should Be Initiated Before Full Funding Authorization

We recommend initiating the P3 procurements (but not complete procurement) before full funding authorization. This will allow for an accelerated process, and for the City to use information gleaned from bidders within the procurement process to be more certain about the level of financial commitment that bidders will need from the City. Under this option, the procurement processes will be initiated before full funding authorization, and closed after final funding approval is secured. If proposals would be submitted prior to funding authorization, they would come with so many caveats and at such a level of generality that the bidding process would not result in the kind of definitive and efficient procurement that could fully protect the City's interests.

9.3.2 The Bids Should Be Requested After Funding Authorization

Funding authorization will provide certainty to bidders about the level of financial commitment available to the project. Additionally, having funding certainty from the City will provide a measure of comfort to investors as they undertake the level of effort and cost required to bid on this opportunity. Furthermore, prior to full funding approval, the City would presumably be unable to award a binding contract.

9.3.3 The Use of Stipends Will Encourage Bidder Participation

The City can encourage bidder participation through a mechanism that is generally used in very large P3 procurements—which is to compensate the bidders for their efforts. This would likely be undertaken with the understanding that the winning bidder's compensation from the City would then be rolled in to the bid itself, and the City's financial obligation for this particular process would extend only to the losing bidders.

This is a viable and tested way to conduct a large, significant-scale procurement, and is frequently used once a subset of bidders (those that are prequalified) are selected. It would likely entail payment between $500,000 and $2 million, given the newness of broadband P3s and the level of effort necessary for each bidder to develop new partnerships, models, and legal analysis.

Appendix A: Glossary

Administrative Fee – The portion of the Connection Fee allocated to funding the administrative efforts of the Public Broadband Enterprise.

Commercial Service Fees – The fee charged to consumers for data services provided by retail services providers.

Connection Fee – The fee assessed to households and businesses to fund the P3s.

CPE (Customer Premises Equipment) – The equipment at the subscriber site that connects to the FTTP network via the subscriber port, such as a router, switch, or set-top box.

Dark Fiber Concessionaire – The private awardee of the P3 for building and maintaining outside plant infrastructure, including fiber optics and hub facilities.

Dark Fiber Connection Fee – The portion of the Connection Fee allocated to funding the Dark Fiber Concessionaire.

Dark Fiber Lease Fees – The lease fees paid by lessees of dark fiber.

Dual P3 Model – The dual P3 structure developed for this initiative that would entail two P3s, one for dark fiber (Dark Fiber P3) and one for lit service (Lit Fiber P3).

Single P3 Model – The alternative P3 structure developed for this initiative that would entail a single P3 for open access dark fiber, with the City playing no role in lighting the fiber or offering services.

EVC (Ethernet Virtual Connection) – A service connection between two or more subscriber ports or RSP access ports.

FDC (Fiber Distribution Cabinet) – A cabinet placed geographically between the network aggregation switches or central office which serves as an aggregation point for fiber that feeds subscriber premises. The cabinet houses either passive optical equipment (such as GPON splitters) or active optical equipment (such as an OLT).

Lit Fiber Concessionaire – The private awardee of the P3 for providing equipment and lit services over dark fiber.

Lit Fiber Connection Fee – The portion of the Connection Fee allocated to funding the Lit Fiber Concessionaire.

NNI (Network-to-Network Interface) – A physical network port that acts as the demarcation point between two service provider networks; in this case, between the City FTTP network and a service provider network.

OLT (Optical Line Termination) – The upstream connection point (to the FTTP network) for subscribers which connects to the ONT. The choice of an optical interface installed in the OLT determines whether the network provisions shared access (one fiber split among multiple subscribers in a GPON architecture) or dedicated active-E access (one port for one subscriber).

ONT (Optical Network Terminal) – A device that sits at the subscriber premises and is connected to fiber from the FTTP. The device converts the network signal between the FTTP optical fiber and the copper Ethernet connection used for the CPE.

Public Broadband Enterprise (PBE) – The entity of San Francisco government that will manage and administer the P3 contract(s), collect Connection Fees, and issue relevant debt.

QoS (Quality of Service) – The means to ensure minimum performance levels for certain network traffic through prioritization and reservation of resources.

Service Provider – The organization providing a network service; most commonly, an internet service provider (ISP).

Subscriber – The individual or organization purchasing a network service.

UNI (User-to-Network Interface) – A physical network port that acts as the demarcation point between the FTTP network and a subscriber network. On an FTTP network, this would usually be a copper Ethernet port on an ONT or an Ethernet switch with an optical upstream interface.

Appendix B: Value-for-Money Assessment and Value-for-Money Drivers

A value-for-money assessment is a structured comparison of delivery methods, usually comparing a conventional delivery model (various single contracts for design, construction, operations) with P3 delivery method (e.g., design, build, finance, operate, and maintain—or DBFOM). The assessment answers the question "which delivery method provides the 'best deal' for implementing a specific project from the perspective of the tax payer or government?"

A value-for-money assessment can be either qualitative or quantitative. For example, for highway and social infrastructure projects, the result of a value-for-money assessment typically is a net present value or percentage difference between a conventional delivery model and a P3 delivery model.

However, an increasing number of governments, in the U.S. and internationally, have decided to de-emphasize the quantitative comparison or move away from the quantitative comparison altogether; this analytical shift reflects the limited data available to justify expected differences between conventional and P3 delivery, and an increase in claims regarding the manipulation of outcomes within the value-for-money assessment.

This trend has led to an increase in purely qualitative value-for-money assessments. Since there is very little data on implementation of city-wide broadband networks, our analysis of the Fiber for San Francisco Initiative did not include a qualitative comparison.

Moreover, for this initiative, there is not really a 'conventional model' that can be realistically implemented. This makes the traditional value-for-money assessment infeasible.

That said, the qualitative arguments around value-for-money are still relevant for structuring and assessing delivery models for the Fiber for San Francisco Initiative. The alternative traditional value-for-money assessment included here discusses the drivers of value-for-money and apply those in the discussion and qualitative comparison of delivery models.

Governance Mechanisms That Drive Value-for-Money

There are five major categories of governance mechanisms within P3 agreements that drive value-for-money, as shown in Figure 16:

1. Integration and life-cycle costing
2. Specifications allowing for innovation
3. Financial incentives
4. Competition
5. Efficient risk allocation

Figure 16: P3 Value Drivers

Governance mechanism	Conventional delivery	P3 delivery
Integration and life cycle costing	Public entity integrates multiple contracts	One contract, private entity is integrator
Specifications allowing for innovation	Input specification, determining design and engineering solutions in detail	Output specification, allowing for creative solutions and life cycle costing
Financial incentives	The payment mechanism usually follows the cost structure of the contractor; for example: milestone payments	The payment mechanism is related to the output specifications and payments are therefore related to performance
Competition	Depending on the public entity, portions of the project can be insourced and are therefore not subject to a competitive bidding process	Competitive bidding for the entire contract
Efficient risk allocation	Risks are not always explicit; most risks are retained by the public entity	Risks are explicit and allocated according to the principle of "whoever is best able to manage the risk" will be responsible

Integration and Life Cycle Costing

Conventional delivery of infrastructure by public entities typically relies on the public entity to integrate multiple contracts—from design, to construction, to a series of operations and maintenance contracts—throughout the life cycle of the project. As such, the public entity holds risk related to integrating these contracted services.

In P3 delivery, a private entity provides all the services for the life cycle of the infrastructure through one contract, thereby taking on the risk of integrating all the different components of the project. Integration of these different components is a foundation for the value that P3s are expected to generate, because the integration aligns incentives for the private entity. For example, the private entity might make specific decisions in project design and construction that could be subsequently advantageous in operations and maintenance.

Output-Based Specifications That Allow for Innovation

In P3 contracts, specifications regarding what the concessionaire provides are output-based, leaving room for the concessionaire to decide how to deliver the services that are required. This contrasts with typical contracts, in which design and engineering solutions are provided in detail, and the private parties simply provide the service to the determined specification. Output-based specifications, in combination with competitive pressure through a bidding process, incentivize concessionaires to come up with creative solutions that seek life-cycle savings and higher quality of service.

Financial Incentives

A P3 can align public and private interests—and incentivize the private sector's performance—through financial incentives and penalties. Positive performance improves the private sector's profits directly through timely, or higher, payments, or indirectly, through lower costs. Poor performance triggers penalties, which will directly affect the financial performance of the concessionaire.

Financial incentives for the concessionaire are structured as a direct relationship with the output-based specifications, and are linked to performance. A key to properly aligning financial incentives is to make sure that the concessionaire has "money at stake." Additionally, financing aligns the interest of debt financiers with the interests of the public entity. The private party will only be paid (and the debt provider repaid) if the project/service is delivered well.

Competition

The benefits of a P3 will only materialize if the concessionaire is procured through a fair, transparent, and competitive process that features multiple, highly-qualified bidders. The foundation of a competitive procurement is market appetite and capacity. A procurement process that features P3 best practices—such as shortlisting of pre-qualified bidders, using a draft RFP process, and limiting appropriations risk upfront—can minimize transaction costs for all parties involved, and can directly affect market appetite.[100]

[100] A note on P3 transaction costs: Limiting transaction costs is also important for the public sector. P3 transactions are typically more complex, and usually require more time, and outside counsel to complete—particularly if a public entity does not have prior experience with procuring P3s. Higher transaction costs for P3s is expected due to the fact that a P3 is essentially one contract that replaces multiple contracts. It is important to note that over the life cycle of a project, transaction costs associated with conventional delivery may be higher than a P3 due to the need to procure multiple contracts, from design, to construction, to financing, to various operations and maintenance contracts.

Another aspect of competition is the procurement evaluation criteria. The goal of every bidder within a competitive procurement process is to win. To win, bidders need to obtain the best score vis-à-vis the evaluation criteria. Therefore, the evaluation criteria should focus on the key public sector objectives for the project. In order to do this, and balance the goal of creating the highest value-for-money, evaluation criteria are not simply price-based, but based on "best-value," which includes achieving public goals.

Efficient Allocation of Risks

The core of a P3 deal is efficient risk allocation. Risk allocation is based on the principle that risks should be allocated to the party that can best manage the risks. Key to risk allocation is recognition that simply because the risk is allocated to a specific party does not mean that the risk does not exist.

Also, regardless of whether the public or the private party assumes the risk, there is a cost associated with bearing the risk, which is reflected in the P3's overall value-for-money. Some risks, such as political risk or risks associated with budget appropriations, are typically best managed by the public sector. Technical and interface risks such as errors and omissions in design, or construction delays, are typically best managed by the private sector. Note that some risks, such as force majeure and technical changes over time, are typically shared between the public and private parties.

Value-for-Money Analysis of Classic P3 Model

The Classic P3 Model does not create the best value-for-many profile for broadband P3 projects because it does not efficiently allocate risks, limits competition, limits output-based specifications, and typically involves high transaction costs. However, this model does allow for financial incentives through performance-based payments and / or revenue sharing.

Efficient allocation of risks: Most risks are allocated to the concessionaire in this model. Given that efficiency is defined as allocation of risks to the party that is the most able and equipped to manage and mitigate the risk, the concessionaire is likely not the best entity to manage all risks associated with long-term revenue for services that tend to change over time.

Integration and life cycle costing: This model does allow for maximum integration of various elements of the project—in particular, integration between dark fiber and lit services. However, as we noted above, this model does come with the risk of producing a quasi-monopoly, which would limit competition for lit services.

Output-based specifications that allow for innovation: This model can allow for output-based specifications. However, it will be challenging to create specifications that are truly output-based in this P3 model, because the economic life of the equipment is only seven to 10 years. This type of infrastructure is highly dynamic, which makes future output-based specifications difficult to anticipate.

Financial incentives through performance-based payments and / or revenue sharing: This model can be structured to allow for financial incentives.

Transaction costs: We would anticipate high transaction costs under this model due to the project's first-of-its-kind nature, the complexity of the project, and the need to determine the source of Connection Fees.

Value-for-Money Analysis of Dual P3 Model

The Dual P3 model seeks to create the best value-for-many through efficient risk allocation, incentivizing competition, and encouraging use of output-based specifications. However, due to the complexity of this project, and the two procurement processes needed, high transaction costs are expected.

Efficient allocation of risks: Risks are allocated to the concessionaire best positioned to manage them. Given that efficiency is defined as allocation of risks to the party that is the most able and equipped to manage and mitigate the risk, the Dark Fiber Concessionaire is the best entity to manage risks associated with the long-term provision of dark fiber infrastructure. In the same vein, the Lit Fiber Concessionaire is the best entity to manage risks associated with revenues for the equipment, network operations, and service provision.

Using a shorter concession term for the Lit Fiber P3 also inherently puts some of the risk associated with revenues that will most likely change over time back into the hands of the City—which allows for the City to also partially manage this risk.

Integration and life cycle costing: This model does allow for maximum integration of various elements of the project—in particular, integration between the dark fiber, network operations, and service provision levels. However, as we noted above, this model does come with the risk of producing a quasi-monopoly, which would limit competition at the service provision level, and potentially also with respect to dark fiber.

Output-based specifications that allow for innovation: This model can allow for output-based specifications. Each P3 contract will include output-based specifications that are appropriate for the economic life of the investment. The shorter concession term for the Lit Fiber P3 will allow the P3 contract (and subsequent P3 contracts) to adequately anticipate changes over a shorter time duration, recognizing the highly dynamic nature of these investments.

Financial incentives through performance-based payments and/or revenue sharing: This model can be structured to allow for financial incentives, including performance-based payments and/or revenue sharing.

Transaction costs: We would anticipate high transaction costs under the Dual P3 Model due to the project's first-of-its-kind nature, the complexity of the project, the need to go to determine the source of Connection Fees, and the fact that two complex procurements will need to be completed in a staggered fashion.

Appendix C: Risk Matrix

The following table summarizes the Project Team's assessment of potential risk factors across a range of project phases.

Category	Description	Risk	Impact	Mitigation Approach	Public	Private
Design	Utility pole owners and attached parties impose excessive engineering requirements and provide poor documentation for existing infrastructure, increasing the difficulty of aerial engineering which results in increased design costs and project delays.	High	Medium	Prior to the engineering phase, alert the various pole owners of the project scope and negotiate a streamlined process for the concessionaire to obtain pole attachment information over the course of the project. Constantly revise priorities and schedules to accommodate unexpected construction roadblocks. Construct underground where necessary. Establish a one-touch make ready practice for a new attacher.	60	40
	Stringent City agency permitting, inspection and restoration requirements increases the difficulty of underground engineering which results in high design costs and project delays.	High	Medium	Work with the City agencies to eliminate non-essential permit requirements. Constantly revise priorities and schedules to accommodate unexpected construction roadblocks. Concessionaire calls in utility locates during the engineering design process for certain areas of the City where underground congestion is expected.	70	30
	Poor documentation of existing infrastructure increase the difficulty of underground engineering which results in increased design costs and project delays.	High	Medium	Develop a process to make sure City agencies provide the best available information on underground utilities to the concessionaire.	100	0
	City agencies change construction standards during the course of the project causing engineering designs to become infeasible or not optimal from a cost perspective. This could result in additional costs and project delays due to design revisions.	Low	Medium	With acceptance from the appropriate City agencies, develop a set of clearly defined construction standards that shall remain valid throughout the duration of the FTTP construction project.	100	0

Category	Description	Risk	Impact	Mitigation Approach	Public	Private
	Delayed responses from City agencies or pole owners when the engineering contractor makes information requests pertaining to engineering or permitting.	High	Low	Work with City agency or pole owner to establish response time requirements for any process that currently does not have defined response times. Identify appropriate POCs for each agency and pole owner.	90	10
	City agencies and/or utility pole owners do not have the capacity to review engineering and provide permits in a timely manner for a project of this scale, causing delays in construction.	High	Medium	Work with the city agencies to eliminate non-essential permit requirements and develop a streamlined process for the various City agencies to review essential permits. Phase the planned aerial construction to account for expected delays with pole attachment review. Prioritize the submission of pole attachment packages so that critical routes are reviewed first.	100	0
	Engineering contractor has difficulty obtaining permission to access commercial buildings and MDUs, resulting in delays or incomplete engineering.	High	Medium	Develop plan to effectively enforce new legislation that requires building owners to allow access to all state-licensed providers.	50	50
Construction	Unanticipated construction requirements and/or obstructions that cannot be identified during the design phase that result in increased costs and project delays.	Medium	High	Concessionaire calls in utility locates during the engineering design process for certain areas of the City where underground congestion is expected.	50	50

Category	Description	Risk	Impact	Mitigation Approach	Public	Private
	Areas of the City may have limited space in the underground ROW resulting in redesign of routes which can increase costs and delayed construction.	Low	High	Concessionaire calls in utility locates during the engineering design process for certain areas of the City where underground congestion is expected.	0	100
	Pole owners such as PG&E and AT&T have a multi-year schedules for pole replacement and make ready work. They do not perform work out of their scheduled order, nor do they provide details of the scheduled work. Significant project delays for aerial builds could occur while waiting for pole owner to perform make ready work. Increased costs for engineering redesign and underground construction may occur if the City builds underground to bypass the delays.	High	High	Negotiate with pole owners to make an exception to their standard process, allowing out of order work to be performed on the City's project. Obtain the detailed work schedule from the pole owner so engineering and construction can be phased to accommodate the planned make ready schedule.	50	50
	Construction contractors are unable to obtain fiber construction materials due to supply shortages causing project delays.	Medium	Medium	If needed the concessionaire can work directly with a fiber cable manufacturer to reserve a spot in the production queue to ensure fiber cable is available during the project.	0	100
	Local utility locating services do not have capacity to keep up with locates requests for a project of this scale, causing delays in construction.	Medium	Medium	Prior to construction, alert local locating services of impending project scope to allow them prepare for the influx of locate requests as best as possible.	50	100

Category	Description	Risk	Impact	Mitigation Approach	Public	Private
	Project contractor damages City-owned or third-party utilities causing delays in construction and project pushback from City agencies or third-party utility owners.	Medium	Medium	Require the selected concessionaire to use multiple construction contractors, so that contactors who have issues with damaging utilities can be removed from the project without compromising the project timeline. Require concessionaire to use construction contractors with experience working in the City and/or a proven track record of low hit rates. Develop additional quality control processes for contractors to implement after they hit a utility.	0	100
Operations	A power outage at core sites or hub facilities causes a service outage on the network.	Low	Medium	Design the network to have backup power at core sites and hub locations. Design network with redundant routing to minimize service outages.	0	100
	Network suffers significant damage from earthquake or other natural disaster.	Low	High	Ensure SLAs are in place to guarantee quick response and repair times for damaged assets. Design network with redundant routing to minimize service outages during repairs.	50	50
	A cyberattack causes a service outages or vulnerability to users on the network.	Medium	Medium	Ensure firewalls and other security measures and best practices are built into the network. Develop a response plan to deal with the attack and restore services.	0	100

Category	Description	Risk	Impact	Mitigation Approach	Public	Private
	Utility construction within the City damages network fiber infrastructure causing outages.	High	Low	Ensure all underground portions of the network have properly registered with 811. Collect accurate as-built documentation at the end of the construction phase to create accessible records of the network infrastructure. Ensure SLAs are in place to guarantee quick response and repair times for damaged assets. Design network with redundant routing to minimize service outages during repairs.	80	20
	Network becomes oversubscribed due to new development in the City and population increase.	Low	Medium	Design additional capacity into the network to accommodate growth.	0	100
	The malfunctioning of equipment placed at or near customer premises resulting in property damage or other City/concessionaire liability.	Low	Medium	Ensure equipment is installed to manufactures specifications, local, and state regulations. Ensure valid permissions are obtained and documented for any installation on customer property.	0	100
	Technologies such as 5G and small cell wireless render a citywide FTTP network obsolete in the near future.	Low	Low	Fiber is the cornerstone technology in wireline and wireless networks. Concessionaire and the City need to be aware of technological and market changes and keep the service offerings relevant.	20	80

Category	Description	Risk	Impact	Mitigation Approach	Public	Private
Financial	Interest rate risk after financial close	High	Low	We expect some level of interest rate fluctuation. To reduce the exposure of this risk for the City, a defined maximum availability payment can be used in the P3 agreements, use a conservative interest rate for planning purposes, and update documents with the latest interest rates.	100	0
	Ability to collect the Connection Fee	Low	High	Structure the Connection Fee such that collections are tied to an existing, "tried and true" process. Currently, the Connection Fee is structured as a parcel tax—which has a history of reliable collections.	100	0
	Bank, market, underwriting, or equity issues arise for either concessionaire that can delay financial close	Low	Medium	Ensure ability to finance the structure during the procurements.	0	100
	The pre-procurement auction does not secure enough in lease revenue to make the project feasible	Medium	Low	Undertake significant pre-marketing and publicizing of the pre-procurement auction	100	0
	Refinancing conditions are not generating material upside	Medium	Low	Use conservative assumptions regarding refinancing.	50	50
Political	Incumbent opposition	High	High	Continue current practice of ongoing outreach to incumbents and create opportunity for participation; recognize, however, that incumbent opposition may persist regardless of steps the City takes	100	0

Category	Description	Risk	Impact	Mitigation Approach	Public	Private
	Delays to City approvals for the P3 contracts or the project	?	Medium	Gain a clear understanding of all City approvals that are needed for this project, and engage with stakeholders early and often.	100	0
	Managing concerns and issues raised by public stakeholders that can stop the project	Medium	Medium	Work with legislators, stakeholders, elected officials, etc. to fully understand public concerns. Prior to financial close, the public will own all of this risk. Post financial close, the concessionaire will want to be engaged in efforts to manage stakeholder issues, and shaping public opinion about the project, and services provided.	80	20
	P3 dark fiber procurement does not garner significant market interest, and does not generate robust competition	Low	High	Engage the market early to understand interest, identify possible issues/show stoppers, etc.	100	0
Procurement	Delays in the procurement process for either P3	High	Medium	Set a realistic schedule for the two P3s, including an appropriate timeframe for review, approvals, etc.	100	0
	Limited competition in subsequent rounds of the lit fiber P3	Medium	Medium	Carefully structure the market and align incentives for the future base level service P3 procurement (in 5-7 years)	100	0

Category	Description	Risk	Impact	Mitigation Approach	Public	Private
	Proposals received in the dark fiber P3 procurement make it very difficult to implement the lit fiber P3	Medium	High	Structure the dark fiber P3 procurement with the base level service P3 in mind, and include dialogue and time delay between the procurements in order to identify and address issues.	100	0
	Bidder appeals of the procurement process, particularly if it is seen to advantage an incumbent, or limit subsequent competition	Low	Medium	Clearly articulate the rules of the procurement process, to limit opportunities for appeal.	100	0
	Distortion of level playing field, lack of a competitive procurement due to collusion, having one bidder secure a very large lease, etc.	Medium	High	Keep an active eye on issues associated with collusion, and manage pre-procurement auction properly to avoid issues of large lessees that are dedicated to one proposer.	100	0

Appendix D: Direct Economic Benefits of Fiber Construction in San Francisco

To determine the potential economic benefits of the Fiber for San Francisco Initiative, the following is an analysis of the potential direct job creation from this initiative, as construction labor and network staffing represents a large portion of the total project cost

CTC engineers undertook an independent analysis of likely job creation based on our experience analyzing, testing, and designing communications networks and on our observations of fiber deployments elsewhere. Our analysis is also based on our direct experience with network projects in other cities that are substantially similar to San Francisco.

In our experience, there are two distinct categories of direct job creation from broadband initiatives: (1) network construction and (2) operations:

The first category of direct jobs will only exist during the three-year project construction period. These jobs relate to the labor associated with construction and deployment of the network (e.g., technicians and construction workers who lay the broadband pipes).[101] This category of job creation includes the direct labor associated with installing the infrastructure components and equipment that takes the fiber to the user location. It also includes construction of wireless tower structures and network electronics.

Fiber construction in San Francisco will have an immediate impact in the construction and information technology sectors. Workers will engage in engineering, planning, and environmental compliance. During the intensive three-year construction period, workers will dig ditches and trenches and place fiber in the ground and on utility poles. Additional workers will place and configure communications equipment, manage installation, repair supporting infrastructure, and interact with customers. Some of these direct benefits will accrue to workers from outside the community. Nonetheless, these workers will benefit the local economy because they will purchase fuel, eat at local restaurants, and sleep in local hotels.

Based on our experience, we conservatively estimate that 309 jobs per year will be created during the three-year construction phase of a San Francisco build-out (Table 27).

[101] Robert D. Atkinson, Daniel Castro and Stephen J. Ezell, "The Digital Road to Recovery: A Stimulus Plan to Create Jobs, Boost Productivity and Revitalize America," ITIF, Jan. 7, 2009, at 2 (http://www.itif.org/files/roadtorecovery.pdf) (accessed May 10, 2017).

Table 27: Estimate of Job Creation During Network Construction

Item	Unit	Avg. Hours Per Unit	Project Scope	Estimated Total Hours	Construction FTEs (3-Year Build Out)
Project Management and Quality Control	Miles	110	1,830	201,300	35
Physical Plant Engineering and Permitting	Miles	80	1,830	146,400	25
Construction	Miles	580	1,830	1,061,400	184
Network Electronics Design and Deployment	Subscribers	1	373,481	373,481	65
TOTAL					309

The second category of direct job creation includes jobs associated with the ongoing operations for both the dark fiber and the network electronics. The network will create skilled jobs as workers install and activate communications equipment and other materials that are essential for the operation of the fiber optics. We estimate that at least 170 jobs will be created per year in the operations phase for fiber maintenance and network operations, including:

- 47 FTEs to operate the fiber portion of the network
- 8 FTE contractors for locates and ticket processing[102]
- 27 FTE contractors for fiber repairs[103]
- 88 FTEs for network operations (e.g., network support, network management, call centers and customer support)

The first three categories of operations' jobs relate to the maintenance of the dark fiber network. The majority of these jobs are likely to be located in or near the City of San Francisco, since they entail maintaining the physical aspects of the network, which cannot be completed remotely. A significant percentage of the final category (network operations, which includes activities related to providing customer service and managing call centers) can be performed in other parts of the country, and perhaps the world.

In sum, we estimate that construction of the 1,830-mile fiber network will support 309 jobs in each of the three years that the project is constructed and an additional 170 jobs throughout the project life.

[102] Based on estimated fees paid to contractor for services in year 5 and thereafter ($712,900), assuming 90 percent of listed expenses attributed to labor costs, $60,000 per FTE, and a 40 percent cost burden per FTE.

[103] Based on estimated fees paid to contractor for services in year 5 and thereafter ($15,040,400), assuming 25 percent of fiber repair expenses attributed to labor costs, $100,000 per FTE, and a 40 percent cost burden per FTE.

Appendix E: Technical Performance Metrics and Standards

Standard Specifications for Construction and Maintenance of the FTTP Network Fiber

The selected Dark Fiber Concessionaire shall provide the design, engineering, permitting, procurement, material coordination, construction, testing, and completion of a fiber optic network, primarily consisting of, but not limited to, the following tasks:

- Develop system-level network designs that meet the City's goals;
- Perform field walk-out and documentation of all fiber routes;
- Prepare GIS-based designs and CAD construction prints of final designs;
- Obtain all necessary permits, including environmental approvals and/or jurisdictional determinations;
- Obtain all necessary agreements for utility pole attachment or third-party conduit use;
- Initiation of utility locate requests through the USA North 811, and strict adherence to all California utility locating laws;
- Sub-surface installation of conduit, primarily through the use of horizontal directional drilling, microtrenching, and trenching, including existing utility locating through test pitting, traffic control, and permanent surface restoration;
- Installation of underground handholes and ground rods, including permanent paved surface restoration;
- Placement of fiber optic cable and tracer wire in conduit;
- Installation of new messenger strand between utility poles for aerial cable construction, to include installation or relocation of guy wires and anchors;
- Lash and/or overlash fiber optic cable to aerial messenger strand;
- Installation of fiber splice enclosures and fiber splicing;
- Installation of telecommunication huts and fiber distribution cabinets;
- Placement and assembly of fiber termination panels and related hardware;
- Optical performance testing of fiber optic strands;
- Ongoing network maintenance and repair; and

- Provision and storage of all materials related to the above construction tasks.

The Concessionaire shall be responsible for identifying and securing suitable space for material and equipment storage and staging during construction.

The Concessionaire will provide regular progress reporting, and will closely coordinate its construction schedule with the City. The Concessionaire shall provide a primary point of contact to the City for the duration of the contract, and shall be expected to attend regular project status and management meetings. The Concessionaire shall provide daily progress reporting and forecasting of the construction locations for the following work day during active construction phases of the project, and shall provide weekly reporting of key progress metrics to be defined by the City.

Network Design Specifications

The design for the FTTP network shall be in accordance with the goals and objectives expressed by the City. The design is limited to the physical layer of the network (conduit, fiber, hub locations, etc.), and does not include network electronics, but must take into account current and emerging FTTP network technologies. It is the intent of the City for the FTTP physical infrastructure to support any current or future mix of Passive Optical Network (PON), Active Ethernet, and/or future technology standard.

Network Construction Specifications

Construction of the network shall be in compliance with the National Electrical Code, the National Electric Safety Code, and applicable industry standards, as well as any and all other applicable Federal, State and local laws and regulations. Construction methods and techniques used shall be in accordance with the recommended practices and procedures published by leading industry manufacturers and trade associations, including but not limited to the following:

- Society of Cable Telecommunications Engineers (SCTE) Recommended Practices for Optical Fiber Construction and Testing;
- Telcordia Blue Book – Manual of Design-Builder's Procedures;
- California Occupational Safety and Health (Cal/OSHA) Division; and
- Federal Occupational Safety and Health Administration (OSHA) regulations.

Construction shall also follow all applicable local standards, including but not limited to the following:

- Department of Public Works Standard Specifications and Plans;

- Department of Public Works Order Number 178,940;
- San Francisco Municipal Transportation Agency Regulations for Working in San Francisco Streets (Blue Book); and
- California Public Utilities Commission General Order 95.

The contractors shall be aware of all standards and their application. Ignorance or lack of knowledge shall not be an excuse for improper work to occur. Any work constructed in violation of any applicable code shall be corrected and re-installed properly at the Contractor's expense.

Construction Material Specifications

Materials used in the construction of the network must meet acceptable industry standards and shall meet the City's specification for each individual item.

Conduit used for the construction of the network will generally have a nominal diameter of 2 inches, unless otherwise directed by the City. Conduit shall be high-density polyethylene (HDPE) roll duct meeting applicable ASTM standards. All supplied conduit shall have a smooth inner wall and smooth outer wall. All conduit shall be pre-lubricated, and contain a pre-installed 1100-pound polyester pull tape.

When microtrenching is used to construct the network, microduct shall be used in place of conduit. Microduct shall be high-density polyethylene (HDPE) that conforms to ASTM D3350-98a, Type III, Category 5, Class B or C and Grade P-34 per ASTM D1248-84, or meets equivalent standards. Unless otherwise directed by the City, microduct shall conform to the following sizes:

- 12mm nominal outside diameter and 8mm nominal inside diameter
- 14mm nominal outside diameter and 10mm nominal inside diameter

The fiber optic cable used for the construction of the network shall be in accordance to the following specifications:

- Ribbon optical cable for backbone applications, containing 12-strand ribbons, conforming to international standards ITU-T G.652.D and Telcordia GR-20.
- Loose buffer tube optical cable for service drop applications, containing 12-strand buffer tubes, in 12 and 24-count sheaths, conforming to international standards ITU-T G.652.D and Telcordia GR-20.
- Delivered on reels holding a contiguous fiber cable length of up to 18,000 feet. The Contractor shall be expected to coordinate cable orders to ensure cable lengths are

provided as needed support contiguous cable runs without splicing (not including mid-sheath splices) according to final engineering designs.

- Comprised of All Dielectric (AD) materials.
- Comprised of a gel-free cable design incorporating dry water-blocking elements.
- Marked, in permanent white characters, with:
  - Manufacturer name
  - Month and year of manufacture
  - Number of optical fibers
  - Sequential length markings, minimum of every two feet, in feet

Specifications for Fiber Testing

Optical performance tests shall be performed for all new and/or repaired cables to validate the optical performance of the entire link, as well as to verify that fiber splicing has occurred according to supplied splice matrices. This testing will consist of bi-directional OTDR testing, as well as direct optical attenuation and continuity testing using a calibrated optical source and power meter. This testing shall occur only after fibers are terminated on both ends of a link, and all intermediate construction and/or splicing involving the re-entry of installed splice cases or handling of the fiber optic cable is completed for a particular segment under test. Electronic documentation of all test results shall be provided to the City.

Testing shall be deemed successfully completed if: (1) maximum fiber losses meet manufacturer specifications, with an allowance for splices and connectors; (2) individual splice losses do not exceed 0.1 dB; and (3) maximum mated connector losses do not exceed manufacturer specifications. Testing will be performed by the Concessionaire’s contractors, and may be observed by the City and other designated representatives of the City. The City may request and/or perform additional testing to verify results prior to accepting test data.

An OTDR shall be used to measure and document splice losses and connector losses. To correctly identify abnormalities at a short range, a 100-meter or longer launch cable shall be used between the OTDR and the fiber under test. Bi-directional traces shall be acquired for each fiber. If the connection of the launch cable to the patch panel requires optimization by the operator, sampling acquisition will commence upon completion of the optimization.

Each fiber will be identified, and the results of the test for each fiber will be recorded as indicated below. The test will be repeated for each of the fibers linking a particular site. All tests will be made at 1310 nm and 1550 nm.

Settings on the OTDR shall reflect the following:

- The Refractive Index shall be set for the actual fiber utilized (commonly-used Corning SMF-28 single mode fiber has a refractive index of 1.4677 at 1310 nm);
- Pulse width no greater than 100 ns (10m) for all fiber lengths;
- Scattering coefficient specified by the fiber manufacturer for each wavelength tested;
- A minimum of 10,000 sampling acquisitions (averages);
- Maximum range set to no more than 10 km for all fiber length less than 10 km;
- Maximum range set to no more than 25 km for fiber lengths greater than 10 km; and
- Event threshold: 0.05 dB.

A uniform file-naming scheme for recorded data shall be used that comply with conventions mutually agreed upon by the City and the Concessionaire.

Installed optical fiber OTDR test documentation shall include:

- Total fiber length;
- Individual fiber traces for complete fiber length;
- Losses of individual splices and connectors;
- Losses of other anomalies;
- Wavelength tested and measurement directions;
- Manufacturer, model and serial number of the test equipment; and
- Name and company of the technician performing the tests.

All data collected at each location during the tests shall be recorded at the time of the tests using electronic means.

Optical power meter measurements shall be made at the same time as the OTDR tests to determine overall fiber loss and to ensure that fibers have appropriate end-to-end continuity (fibers not crossed). Power meter testing shall be performed at both 1310 nm and 1550 nm and shall report the relative loss of each fiber strand.

Fiber Maintenance Requirements

Fiber maintenance and emergency repair services shall be made available on a 24x7x365 basis. The Dark Fiber Concessionaire shall have a reasonable inventory of materials and vehicles normally supplied under the terms of this contract for maintenance requests and emergency repairs. These items below describe the minimum level of service the Dark Fiber Concessionaire shall provide to the Lit Fiber Concessionaire and the City. Exact terms should be determined on a case-by-case basis and stated in an SLA with the Lit Fiber Concessionaire.

- Mean time to acknowledge: 1 hour
- Mean time to respond: 4 hour
- Mean time to repair fiber: 24 hours

Time to acknowledge means time for the Dark Fiber Concessionaire to acknowledge receipt of the service request and verbally communicate an acceptable plan of action to resolve service request submitted by the City or Lit Fiber Concessionaire.

Time to respond means time to arrive at the location of fiber damage, with all necessary equipment and personnel resources to make repairs.

Performance Requirements for the Lit Network

The selected Lit Fiber Concessionaire shall provide operation of the network's lit services, primarily consisting of, but not limited to, the following tasks:

- Transport of the network's services;
- Design and operation of the Civic Network;
- NOC (network operations center) services which include monitoring, troubleshooting, and fixing the transport network;
- Providing support and provisioning services for Retail Service Providers; and
- Engaging the Dark Fiber Concessionaire when a fix or new fiber installation is required.

Lit Network Performance Specifications

The Lit Fiber Concessionaire shall supply and provision network electronics capable of delivering highly-available transport for a variety of services over the dark fiber. Transport services shall meet or exceed a Committed Information Rate (CIR) of 50 Mbps with the ability to provide a range of upstream and downstream speeds up to symmetrical 1 Gbps speeds from the Provider Port to the point of network interface.

Transport services provided by the Concessionaire shall meet the following minimum performance requirements for any link between a RSP port and a subscriber port or between any two subscriber ports on the network.

- Network availability (monthly): 99.9%
- Packet loss: < 0.3%
- Latency (one-way): < 10 ms
- Jitter (one-way): < 3 ms

Network Monitoring Requirements

The Lit Fiber Concessionaire shall also provide NOC services to monitor the network and act as the central point of contact for service requests and trouble reports from service providers. For requests that fall outside their scope responsibilities, the NOC shall be responsible for dispatching the correct team. These items below describe the minimum level of service the NOC shall provide to RSPs. Exact terms should be determined on a case-by-case basis and stated in an SLA with each RSP.

- Mean time to acknowledge: 15 minutes
- Mean time to provision (excluding fiber and electronics): 4 hours
- Mean time to respond: 4 hours
- Mean time to repair (excluding fiber): 6 hours
- Mean time to repair fiber: 24 hours

Time to acknowledge means time for a NOC representative to acknowledge receipt of a service request or trouble report submitted by an RSP. This excludes automated responses.

Time to provision means time to provision an existing service EVC to an existing subscriber port. This excludes cases that require new fiber, new service drops, or new electronics.

Time to respond means time to arrive on site with electronics or arrive at location of fiber damage, whichever is applicable.

Appendix F: List of Information to Be Available to Bidders

This appendix identifies information deemed useful to a Master Developer looking to build a ubiquitous broadband network (such as FTTP) throughout the City. The datasets identified in this report are categorized by the type of information they contain, including:

1. City and third-party infrastructure
2. Public right-of-way and City-owned property
3. Potential network users
4. Construction standards and restrictions

For each category, this appendix identifies what data are available, recommends what additional data should be collected, and proposes a method for the collection of the additional data.

City and Third-Party Infrastructure

City-owned or third-party infrastructure that exists within the public right-of-way (e.g., conduit or utility poles) may prove beneficial to a Master Developer that can leverage those assets to reduce its construction costs and avoid the challenges of the City's crowded rights-of-way.

Existing infrastructure could also present obstructions and potential complications during construction. Underground utilities such as gas, water, and sewer take up space in the right-of-way and may make construction of new utilities difficult in some locations. Additionally, street furniture, which may provide value for wireless deployments, can also present obstacles for certain types of underground construction.

Available Data

The City has some data on existing infrastructure, but most of the datasets provide limited information beyond the location of the asset. A Master Developer could use this information to get a general sense of the assets in the City, but additional work would be required to make the data more useful. Table 28 identifies data that are available for use by a Master Developer.

Table 28: Available Information on Existing Infrastructure

ID #	Dataset
2.1.1	San Francisco Department of Technology Fiber Map
1.1.2	San Francisco Department of Public Works Utility Undergrounding Map
2.1.3	San Francisco Public Utilities Commission Conduit, Pullboxes, and Street Lights
2.1.4	San Francisco Municipal Transportation Agency Conduit Map
2.1.5	San Francisco Municipal Transportation Agency Routes and Stops
2.1.6	San Francisco Municipal Transportation Overhead Lines Trolley Pole Database 150813
2.1.7	San Francisco Municipal Transportation Map of Traffic Signals
2.1.8	San Francisco Department of Public Works Map of Street Trees

San Francisco Department of Technology Fiber Network Map

This dataset provides a map of the municipal fiber network operated by the Department of Technology (DT). The map also identifies which portions of the network are underground and which are aerial. This information may be useful as a Master Developer may be able to utilize additional conduit space on the underground fiber routes or overlash to the City's aerial routes to reduce construction expenses. DT can provide this map to the Master Developer.

San Francisco Department of Public Works Utility Undergrounding Map

This dataset is a geocoded map of where the power and telecommunications utilities are underground. The dataset does not contain any specific information about the utilities, just that utilities are located underground. This dataset may inform a Master Developer of where aerial construction may not be possible. This map can be made available to the Master Developer by the San Francisco Public Utilities Commission (SFPUC).

San Francisco Public Utilities Commission Conduit, Pullboxes, and Streetlights

This dataset provides a geocoded map of all SFPUC-owned conduit installed prior to September 2005, as well as data on SFPUC streetlights and pullboxes. This conduit information may be useful to a Master Developer that seeks to use existing conduit space to reduce its construction expenses. The information on streetlight locations may be useful when looking at Smart City applications or hybrid 5G solutions that require equipment to be mounted on structures. This map can be made available to the Master Developer by the SFPUC.

San Francisco Municipal Transportation Agency Conduit Map

This dataset provides geospatial data for the fiber cable conduit used by the traffic signal network (SFGo). All other information on SFMTA conduit is kept in paper records, which may not capture all of the existing conduit routes. If SFMTA is willing to allow access to its conduit, this information may be useful to a Master Developer that seeks to use existing conduit space to reduce its construction expenses. This dataset can be made available to the Master Developer by the SFMTA.

San Francisco Municipal Transportation Agency Routes and Stops

This dataset provides a map SFMTA's route and stop locations. While this dataset does not show conduit or fiber locations, SFMTA's light rail network has conduit and fiber along the routes and may provide a good starting point for further investigation. The dataset also identifies whether a stop is sheltered, which may help to identify street furniture where 5G equipment could be mounted. This dataset can be found on dataSF via the link below.

SFMTA Routes and Stops Map: https://data.sfgov.org/Transportation/SFMTA-routes-and-stops-for-March-2012/f5c3-8kkj

San Francisco Municipal Transportation Overhead Lines Trolley Pole Database 150813

This dataset provides estimated locations of poles supporting electric distribution wires for trolley lines—however, the data are 30 years old. It is possible that under some circumstances these poles could be used to support aerial fiber deployment. This dataset can be provided to a Master Developer by SFMTA.

San Francisco Municipal Transportation Map of Traffic Signals

This dataset provides maps of locations where the City has traffic signals. This information may be useful to a Master Developer as it provides the general location of traffic cabinets which could potentially serve as hub locations for the FTTP network or a Smart City network. The traffic signal map can be found on dataSF via the link below.

Traffic Signal Map: https://data.sfgov.org/Transportation/Map-of-Traffic-Signals/8xta-sna8

San Francisco Department of Public Works Street Tree Map

This dataset provides a map of the locations of DPW-owned and maintained street trees. This information may be useful to a Master Developer because knowing the locations of the trees will allow the Master Developer to anticipate potential conflicts with the microtrenching construction methodology or where tree trimming may be required during aerial construction. Additionally, the trees may pose an issue to any potential hybrid 5G solution with equipment that requires direct line-of-sight. The street tree map can be found on dataSF via the link below.

DPW Street Tree Map:
https://data.sfgov.org/browse?q=Street%20Tree%20Map&sortBy=relevance&utf8=%E2%9C%93

Additional Data Recommendations

While the City has some data on existing infrastructure, the existing datasets would benefit from a higher level of detail. Additionally, the collection of data for several key utilities would provide value. The following data would be useful for a Master Developer.

Collect Utility Pole Data from Other NCJPA Members

Having access to information on the locations of utility poles would be useful for a Master Developer as it would help them to assess options for aerial construction within the City. As a member of the Northern California Joint Pole Association (NCJPA), the City can request maps of pole locations from PG&E, AT&T, and other owners. The City could provide this information to a selected Master Developer under a Non-Disclosure Agreement (NDA). We recommend that the City work directly with the pole owners to obtain this information if possible. Ideally, the information could be provided in GIS format as part of a complete database of spatially accurate pole locations. However, it is possible the pole locations can only be provided in paper map books or another format. At the very least the City should alert the NCJPA members to the possibility of an influx of data requests, and prepare a process to facilitate the transfer of information from the pole owners to the selected Master Developer. Example service requests can be found in Appendix B.

Identify Third-Party Conduit Locations

Identifying locations where third-party utility owners such as PG&E or AT&T have existing conduit infrastructure would be useful to a Master Developer that might want to lease spare conduit space to reduce its construction expenses. We recommend that the City request maps identifying locations of leasable conduit routes from PG&E, AT&T, and other entities that own conduit within the City. Obtaining this information in GIS format would be ideal, but it is unlikely data will be available in that format. The City could digitize any datasets provided on paper to create a GIS database that could be provided to a Master Developer.

Public Right-Of-Way and City-Owned Property

A Master Developer would be interested in understanding the boundaries for which new infrastructure could be placed within. Useful information includes the identification of public right-of-way and City easements where conduit and fiber optic cable could be placed. Additionally, information identifying public property where structures such as telecom huts or cabinets can be placed (i.e., to house equipment needed for the distribution and operation of the network) would be important to a Master Developer.

Available Data

The City already has a fair amount of data available identifying boundaries where infrastructure could be placed. Table 29 identifies datasets that are available for use by a Master Developer.

Table 29: Available Information on ROW and Public Property

ID #	Dataset
3.1.1	San Francisco Department of Public Works Right-of-Way and Easement Information
3.1.2	Facility System of Record (FSR)
3.1.3	Map of Schools
3.1.4	Recreation and Parks Properties
3.1.5	Parcels with Planning Department Zoning

San Francisco Department of Public Works Right-of-Way and Easement Information

This dataset provides right-of-way polygons apportioned into street segments and intersection areas. It provides a representation of the street and easement right-of-way areas, but it does not provide engineering levels of spatial accuracy. This data could be used by a Master Developer to identify right-of-way and easement locations to help inform the initial network design. The right-of-way polygon information can be found on dataSF via the link below.

Right-of-Way Polygons: https://data.sfgov.org/City-Infrastructure/Right-of-Way-Polygons/a2mg-gwmg

Facility System of Record (FSR)

This dataset provides the City's best available list of public property, including City-owned and leased facilities, and facilities owned by non-City public entities. This dataset would inform a Master Developer of possible locations for the placement of structures to house the equipment needed to distribute and operate the FTTP services. Identifying these structure locations is a crucial part of the initial design process. The Facility System of Record list can be made available by DT.

Map of Schools

This dataset details the location of all schools (Infant, Pre-K, and K-12). The data points can be combined with parcel data to identify school property limits. The school location data point information can be found on dataSF via the link below.

Map of School Locations: https://data.sfgov.org/Economy-and-Community/Map-of-Schools/qb37-w9se

Recreation and Parks Properties

This dataset details data points of property owned and maintained by the San Francisco Recreation and Parks Department. The information includes parks and other types of open spaces within the City. The data points can be combined with parcel data to identify property limits. The Recreation and Parks property information can be found on dataSF via the link below.

Recreation and Parks Property Locations: https://data.sfgov.org/Culture-and-Recreation/Park-and-Open-Space-Map/4udc-s3pr

Parcels with Planning Department Zoning

This dataset contains every parcel in San Francisco and each parcel's zoning. This information can be found on dataSF via the link below.

Parcels with Zoning Information: https://data.sfgov.org/City-Infrastructure/Parcels-With-Planning-Department-Zoning/6b2n-v87s

Additional Data Recommendations

The available datasets should provide enough information for purposes of the initial network design. A Master Developer will need to perform additional research as part of the detailed design engineering to ensure that new infrastructure is placed properly within the public space.

Potential Network Users

The City's goal is to build a ubiquitous communications network that will provide fiber to every home and business within San Francisco. To achieve this, a Master Developer would need to understand the quantity and location of potential users.

Available Data

The City has a few datasets that will provide a good starting point for a Master Developer to begin the process of identifying service locations. Table 30 identifies datasets available for use.

Table 30: Available Information on Potential Users

ID #	Dataset
4.1.1	Addresses with Units from the City's Enterprise Addressing System (EAS)
4.1.2	Department of Planning Land Use Map
4.1.3	Treasurer-Tax Collector Registered Business Locations

Addresses with Units from the City's Enterprise Addressing System (EAS)

This dataset lists all active addresses from the City's Enterprise Addressing System, including sub-addresses, such as individual units. The Master Developer could use this dataset to identify service locations in the City, which will help inform the initial network design. The EAS can be found on dataSF via the link below.

EAS: https://data.sfgov.org/Geographic-Locations-and-Boundaries/Addresses-with-Units-Enterprise-Addressing-System-/dxjs-vqsy

Department of Planning Land Use Map

This dataset details the land use information for each parcel within the City and identifies the number of residential units located on that parcel. The dataset does not include unregistered or illegal residential units, nor does it include any information on non-residential buildings. This dataset will be useful because it provides the number of residential units for each parcel; the Master Developer may be able to use these data in conjunction with the Registered Business Location dataset to identify the density of users for a given area, which will help inform the initial network design. The Land Use Map can be found on dataSF via the link below:

Land Use Map: https://data.sfgov.org/Housing-and-Buildings/Land-Use/us3s-fp9q

Treasurer-Tax Collector Registered Business Locations

This dataset lists the street address and latitude-longitude coordinates of each registered business in the City. This dataset will be useful to map the locations of all businesses throughout the City. The Master Developer may be able to use this dataset in conjunction with residential information from the Land Use Map to identify the density of users for a given area, which will help inform the initial network design. The registered business locations can be found on dataSF via the link below.

Registered Business Locations: https://data.sfgov.org/Economy-and-Community/Registered-Business-Locations-San-Francisco/g8m3-pdis

Additional Data Recommendations

The available datasets should be sufficient for a Master Developer to identify the potential users and service locations for proposes of the initial network design. As part of the detailed design engineering, the Master Developer should confirm the total number of service locations while performing the site survey work.

Construction Standards and Restrictions

As the scope of this project will require citywide construction, it is important that the Master Developer understands the City's approved construction standards and restrictions. This will allow them to better understand the level of effort required for the project and help them to make appropriate assumptions on how the network can be built. Important information would include approved construction methodologies, standard specifications, identification of jurisdictional restrictions, and permitting processes.

Available Data

Table 31 identifies datasets that are available for use by a Master Developer.

Table 31: Available Information on Construction Standards and Restrictions

ID #	Dataset
5.1.1	California Public Utilities Commission General Order No. 95 (GO 95)
5.1.2	Northern California Joint Pole Association Operations/Routine Handbook 2016
5.1.3	San Francisco Municipal Transportation Agency Regulations for Working In San Francisco Streets (Blue Book)
5.1.4	Department of Public Works Standard Specifications and Plans
5.1.5	Department of Public Works Excavation Regulations
5.1.6	AT&T General Terms and Conditions for Conduit Use
5.1.7	PG&E Conduit License Agreement
5.1.8	Department of Public Works Utility Excavation Moratorium Streets List
5.1.9	Department of Public Works Pavement Condition Index (PCI) Scores List
5.1.10	City Projects for Utility Excavation and Paving

California Public Utilities Commission General Order No. 95 (GO 95)

This document provides rules and requirements for overhead line design, construction, and maintenance within the State of California and is applicable to utility poles within the City. The

Master Developer could use this information to understand the effort required to construct aerially within the City.

A link to each of the sections of GO 95 can be found on California Public Utilities Commission's website via the following link: http://www.cpuc.ca.gov/gos/GO95/go_95_section_1.html

Northern California Joint Pole Association Operations/Routine Handbook 2016

This document provides a comprehensive overview of the pole attachment process for all joint-owned poles within the City. Information in the document includes the attachment process for joint owners, attachment standards, and authorized costs. The Master Developer could use this information to understand the pole attachment process and the effort required to construct aerially within the City. As a member of the NCJPA, the City has access to this document and can provide it to the selected Master Developer.

San Francisco Municipal Transportation Agency Regulations for Working in San Francisco Streets (Blue Book)

This document is a manual for City agencies (DPW, Muni, SFWD, DPT, Port of SF, etc.), utility crews, private contractors, and others doing work in San Francisco's streets. It establishes rules for working safely and in a way that will cause the least possible interference with pedestrian, bicycle, transit, and other traffic. The document includes requirements for permitting, traffic control procedures, and agency contact information—all which would be useful for a Master Developer.

A link to each of the sections of the standard specification document can be found on SFMTA's website via the following link: https://www.sfmta.com/services/streets-sidewalks/construction-regulations

Department of Public Works Standard Specifications and Plans

The Standard Specifications provide information on the City's requirements for various types of construction projects, including types of construction that would overlap with fiber construction. The specifications that will most likely be useful for a Master Developer would be found in the electrical work, excavation and backfill, and landscaping work sections of the document.

A link to each of the sections of the standard specification document can be found on DPW's website via the following link: http://sfpublicworks.org/services/standards-specifications-and-plans

This webpage also provides links to DPW's standard plans for pullboxes as well as other information that may be useful for the Master Developer.

Department of Public Works Excavation Regulations

This group of documents provides compete detail on the City's rules and regulations regarding excavation in the public right-of-way. This information will be useful to a Master Developer because a citywide FTTP build will most likely require a substantial amount of excavation within the City.

A link to each of these documents can be found under the Excavation Regulations section of the Project Manual and Reference Documents page of DPW's website, which can be accessed via the following link: http://sfpublicworks.org/services/project-manual-and-reference-documents

AT&T General Terms and Conditions for Conduit Use

This document provides the general terms and conditions for access and use of AT&T's conduit in the City. This information will be useful to a Master Developer because leveraging existing conduit infrastructure in the City may be a viable way to reduce the overall project cost. The City has access to this document and can provide it to the selected Master Developer. While the Master Developer will need to obtain its own agreement with AT&T, this document will provide and understanding of what the Master Developer can expect.

PG&E Conduit License Agreement

This document outlines the process for applying to gain access to PG&E conduit, the rules and regulations for use of the conduit, and an overview of the estimated pricing to use the conduit. This information will be useful to a Master Developer because leveraging existing conduit infrastructure in the City may be a viable way to reduce the overall project cost. The City has access to this document and can provide it to the selected Master Developer. While the Master Developer will need to obtain its own agreement with PG&E, this document will provide and understanding of what the Master Developer can expect.

Department of Public Works Utility Excavation Moratorium Streets List

This dataset identifies the streets within San Francisco that are under a utility excavation moratorium. This information may be useful as it will help identify streets where a Master Developer would need to avoid street excavation or obtain a special waiver from DPW. A Master Developer could potentially use this information to inform project phasing and other planning considerations. The utility excavation moratorium streets list can be found on dataSF via the link below.

Utility Excavation Moratorium Streets List: https://data.sfgov.org/City-Infrastructure/Utility-Excavation-Moratorium-Streets/5wbp-dwzt

Department of Public Works Pavement Condition Index (PCI) Scores List

This dataset provides information on the condition of the pavement for more than 12,800 streets in San Francisco. This information may be useful as it will help identify locations where DPW will be more amenable to underground and excavation work. A Master Developer could potentially use this information to inform project phasing and other planning considerations. The PCI spreadsheet can be found on dataSF via the link below.

PCI: https://data.sfgov.org/City-Infrastructure/Streets-Data-Pavement-Condition-Index-PCI-Scores/5aye-4rtt

City Projects for Utility Excavation and Paving

This dataset provides information on planned excavation and pavement projects, including both public and private capital/utility projects. This information may be useful as because it could allow a Master Developer to reduce its costs by potentially coordinating construction efforts with other ongoing projects. This information could inform the network design, project phasing, and other planning considerations. The utility excavation and paving projects list can be found on dataSF via the link below.

Utility Excavation and Paving Projects List: https://data.sfgov.org/City-Infrastructure/Envista-Projects-for-Utility-Excavation-and-Paving/sf93-6dmr

Additional Data Recommendations

The City has a significant amount of documentation relating to construction standards and restrictions. Compiling this information into a format that could be easily reviewed and understood would be beneficial to a Master Developer. Accordingly, we make the following recommendations.

Develop Standard Specifications for Fiber Construction

The Department of Public Works has standard specifications and design plans for various types of construction, including streets and highways, structures, electrical work, excavation and backfill, and landscaping. While some of these standards overlap with work that would be conducted in a citywide FTTP project, many standards that are specific to fiber construction are not covered in the existing specifications. Developing a single document that clearly defines approved construction methodologies and practices for this specific project would be very beneficial to a Master Developer.

CTC recommends that a set of standards be developed specifically for fiber construction within the City and that the development of this document should be a collaboration between DT and DPW.

Finalize Standards for Microtrenching

The City has approved legislation for an ordinance amending the Public Works Code to allow the use of microtrenching to install fiber-optic cables in the sidewalk portion of the public right-of-way. While this document will provide some guidance to a Master Developer on the proposed regulations for microtrenching in the City, there are still certain parameters of this construction methodology that require clarification and acceptance from DPW.

CTC recommends that the City finalize outstanding requirements for microtrenching and develop a set of DPW-approved standards that a Master Developer could use for guidance. The approved microtrenching standards could be included as part of the standard specifications document for general fiber construction.

Table of Available Datasets

ID #	Dataset	Resource
2.1.1	Department of Technology Fiber Map	Brian Roberts, (415) 581-4061, Brian.Roberts@sfgov.org
1.1.2	Department of Public Works Utility Undergrounding Map	Joy DiFranza, (415) 554-5813, joy.difranza@sfdpw.org
2.1.3	San Francisco Public Utilities Commission Conduit, Pullboxes, and Street Lights	SFPUC Team, streetlights@sfwater.org
2.1.4	San Francisco Municipal Transportation Agency Conduit	Ramon Zamora, (415) 701-5668, Ramon.Zamora@sfmta.com
2.1.5	San Francisco Municipal Transportation Agency Routes and Stops for March 2012	dataSF:https://data.sfgov.org/Transportation/SFMTA-routes-and-stops-for-March-2012/f5c3-8kkj
2.1.6	San Francisco Municipal Transportation Overhead Lines Trolley Pole Database 150813	Tee Phang, (415) 701-4239, Tee.Phang@sfmta.com
2.1.7	San Francisco Municipal Transportation Map of Traffic Signals	dataSF:https://data.sfgov.org/Transportation/Map-of-Traffic-Signals/8xta-sna8
2.1.8	Department of Public Works Map of Street Trees	dataSF: https://data.sfgov.org/browse?q=Street%20Tree%20Map&sortBy=relevance&utf8=%E2%9C%93
3.1.1	Department of Public Works ROW and Easement Information	dataSF:https://data.sfgov.org/City-Infrastructure/Right-of-Way-Polygons/a2mg-gwmg
3.1.2	Facility System of Record (FSR)	Brian Roberts, (415) 581-4061, Brian.Roberts@sfgov.org
3.1.3	Map of Schools	dataSF: https://data.sfgov.org/Economy-and-Community/Map-of-Schools/qb37-w9se
3.1.4	Recreation and Parks Properties	dataSF: https://data.sfgov.org/Culture-and-Recreation/Park-and-Open-Space-Map/4udc-s3pr
3.1.5	Parcels with Planning Department Zoning	dataSF:https://data.sfgov.org/City-Infrastructure/Parcels-With-Planning-Department-Zoning/6b2n-v87s
4.1.1	Addresses with Units from the City's Enterprise Address System (EAS)	dataSF:https://data.sfgov.org/Geographic-Locations-and-Boundaries/Addresses-with-Units-Enterprise-Addressing-System-/dxjs-vqsy
4.1.2	Department of Planning Land Use Map	dataSF: https://data.sfgov.org/Housing-and-Buildings/Land-Use/us3s-fp9q
4.1.3	Treasurer-Tax Collector Registered Business Locations	dataSF: https://data.sfgov.org/Economy-and-Community/Registered-Business-Locations-San-Francisco/g8m3-pdis

ID #	Dataset	Resource
5.1.1	California Public Utilities Commission General Order No. 95 (GO 95)	CPUC Website: http://www.cpuc.ca.gov/gos/GO95/go_95_section_1.html
5.1.2	Northern California Joint Pole Association Operations/Routine Handbook 2016	Brian Roberts, (415) 581-4061, Brian.Roberts@sfgov.org
5.1.3	San Francisco Municipal Transportation Agency Regulations for Working In San Francisco Streets (Blue Book)	SFMTA Website: https://www.sfmta.com/services/streets-sidewalks/construction-regulations
5.1.4	Department of Public Works Standard Specifications and Plans	DPW Website: http://sfpublicworks.org/services/standards-specifications-and-plans
5.1.5	Department of Public Works Excavation Regulations	DPW Website: http://sfpublicworks.org/services/project-manual-and-reference-documents
5.1.6	AT&T General Terms and Conditions for Conduit Use	Brian Roberts, (415) 581-4061, Brian.Roberts@sfgov.org
5.1.7	PG&E Conduit License Agreement	Brian Roberts, (415) 581-4061, Brian.Roberts@sfgov.org
5.1.8	Department of Public Works Utility Excavation Moratorium Streets List	dataSF: https://data.sfgov.org/City-Infrastructure/Utility-Excavation-Moratorium-Streets/5wbp-dwzt
5.1.9	Department of Public Works Pavement Condition Index (PCI) Scores List	dataSF: https://data.sfgov.org/City-Infrastructure/Streets-Data-Pavement-Condition-Index-PCI-Scores/5aye-4rtt
5.1.10	City Projects for Utility Excavation and Paving	dataSF: https://data.sfgov.org/City-Infrastructure/Envista-Projects-for-Utility-Excavation-and-Paving/sf93-6dmr

Third-Party Data Requests

Data Request to PG&E

PG&E has a large amount of infrastructure in the City including utility poles and conduit that could be leveraged in a Citywide fiber build. As a power company, PG&E does not provide services that would compete with the City's proposed FTTP network and should be more amenable to the City's data requests then telecom providers such as AT&T. With the current NCJPA guidelines, the burden for data collection generally falls to the entity looking to attach as opposed to the pole owner. Because PG&E is not usually required to facilitate access to their data, the odds are low that they would be willing to freely provide information without incentive. It could be expected that the more effort required by PG&E to provide the data, the less likely they will be willing to provide the data.

Obtaining from a power company is not impossible, an awardee of a Broadband Technology Opportunities Program (BTOP) grant, Howard County Maryland was able to successfully obtain geospatial data containing utility pole locations for the entire footprint of their local power company, Baltimore Gas and Electric. This allowed the County to identify aerial attachment opportunities and make informed engineering decisions that benefited their fiber construction project.

Prior to sending the data request, the City should identify the proper point of contact(s) to handle the request. PG&E will most likely have separate contacts for utility poles and underground infrastructure. The data request should include an overview of the proposed project and state the City's willingness to comply with non-disclosure requirements.

The City should request the following information:

#1	**Utility Pole Locations**
Geospatial data identifying the location of all utility poles are located within the City should be requested. The data should be provided in GIS format if possible to allow for easy transfer and review of the information. Though not preferred, paper maps of the pole locations would be better than receiving no data. Paper maps may require more effort from PG&E to provide the information, so the City may consider requesting data for specific sections of the City to increase the likelihood of obtaining the data.	
#2	**Conduit Locations**
Geospatial data identifying the locations of available conduit routes should be requested. The data should be provided in GIS format if possible. Though not preferred, a paper map of the general location of available conduit within the City would be better than receiving no data, as it could provide a starting point for further investigation.	

#3	Utility Pole Information
Specific information on PG&E's poles should be requested to help with analyzing the feasibility of aerial construction. Useful data would include the following: • Individual pole information including; pole class, height, age, material, compliance • Current attachments and loading analysis for individual poles • PG&E's pole replacement and make ready schedule It is possible PG&E has some of the individual pole data in GIS format which would be preferred, though they should have paper records of this data as this information is provided to them every time a new attachment is made.	
#4	**Conduit Information**
Specific information on PG&E's available conduit would provide additional benefit. Useful data would include the following: • Conduit size • Current occupancy and available space • Access points (i.e. handhole locations, building entrances) PG&E may have some of the conduit attributes in GIS format which would be preferred, though it is more likely they have paper records of this information.	
#5	**Abandoned Gas Lines**
Geospatial data identifying the locations of abandoned gas line could be requested. When permitted by the utility owner, fiber can be placed in the abandoned lines to avoid new fiber construction. Abandoned gas lines tend to be less useful because the lack of access points and general placement of the utility make accessing the fiber difficult. Ideally this information could be provided in GIS format, however paper maps would be acceptable.	

Data Request to AT&T

AT&T has a large amount of infrastructure in the City including utility poles and conduit that could be leveraged in a Citywide fiber build. It is possible that AT&T could see the City's proposed network as a competitor and reluctant to provide information to the City. With the current NCJPA guidelines, the burden for data collection generally falls to the entity looking to attach as opposed to the pole owner. Because AT&T is not usually required facilitate access to their data, the odds are low that they would be willing to freely provide information without incentive. It could be expected that the more effort required by AT&T to provide the data, the less likely they will be willing to provide the data.

Prior to sending the data request, the City should identify the proper point of contact(s) to handle the request. AT&T will most likely have separate contacts for utility poles and underground infrastructure. The data request should include an overview of the proposed project and state the City's willingness to comply with non-disclosure requirements.

The City should request the following information:

#1	Utility Pole Locations
Geospatial data identifying the location of all utility poles are located within the City should be requested. The data should be provided in GIS format if possible to allow for easy transfer and review of the information. Though not preferred, paper maps of the pole locations would be better than receiving no data. Paper maps may require more effort from AT&T to provide the information, so the City may consider requesting data for specific sections of the City to increase the likelihood of obtaining the data.	

#2	Conduit Locations
Geospatial data identifying the locations of available conduit routes should be requested. The data should be provided in GIS format if possible. Though not preferred, a paper map of the general location of available conduit within the City would be better than receiving no data, as it could provide a starting point for further investigation.	

#3	Utility Pole Information
Specific information on AT&T's poles should be requested to help with analyzing the feasibility of aerial construction. Useful data would include the following: • Individual pole information including; pole class, height, age, material, compliance • Current attachments and loading analysis for individual poles • AT&T's pole replacement and make ready schedule It is possible AT&T has some of the individual pole data in GIS format which would be preferred, though they should have paper records of this data as this information is provided to them every time a new attachment is made.	

#4	Conduit Information
Specific information on AT&T's available conduit would provide additional benefit. Useful data would include the following: • Conduit size • Current occupancy and available space • Access points (i.e. handhole locations, building entrances) • Information on the terms and conditions to include any applicable service restrictions AT&T may have some of the conduit attributes in GIS format which would be preferred, though it is more likely they have paper records of this information.	

Data Request to Other Providers

Other providers such as Zayo, CenturyLink, and Crown Castle have underground infrastructure in the City that could be leveraged in a Citywide fiber build. It is possible that these entities would be willing to provide information of their available conduit routes, and may offer additional benefit in return such as joint build opportunities during the citywide fiber construction.

Prior to sending the data request, the City should identify the proper point of contact(s) to handle the request. The data request should include an overview of the proposed project and state the City's willingness to comply with non-disclosure requirements.

The City should request the following information:

#1	**Conduit Locations**
Geospatial data identifying the locations of available conduit routes should be requested. The data should be provided in GIS format if possible. Though not preferred, a paper map of the general location of available conduit within the City would be better than receiving no data, as it could provide a starting point for further investigation.	

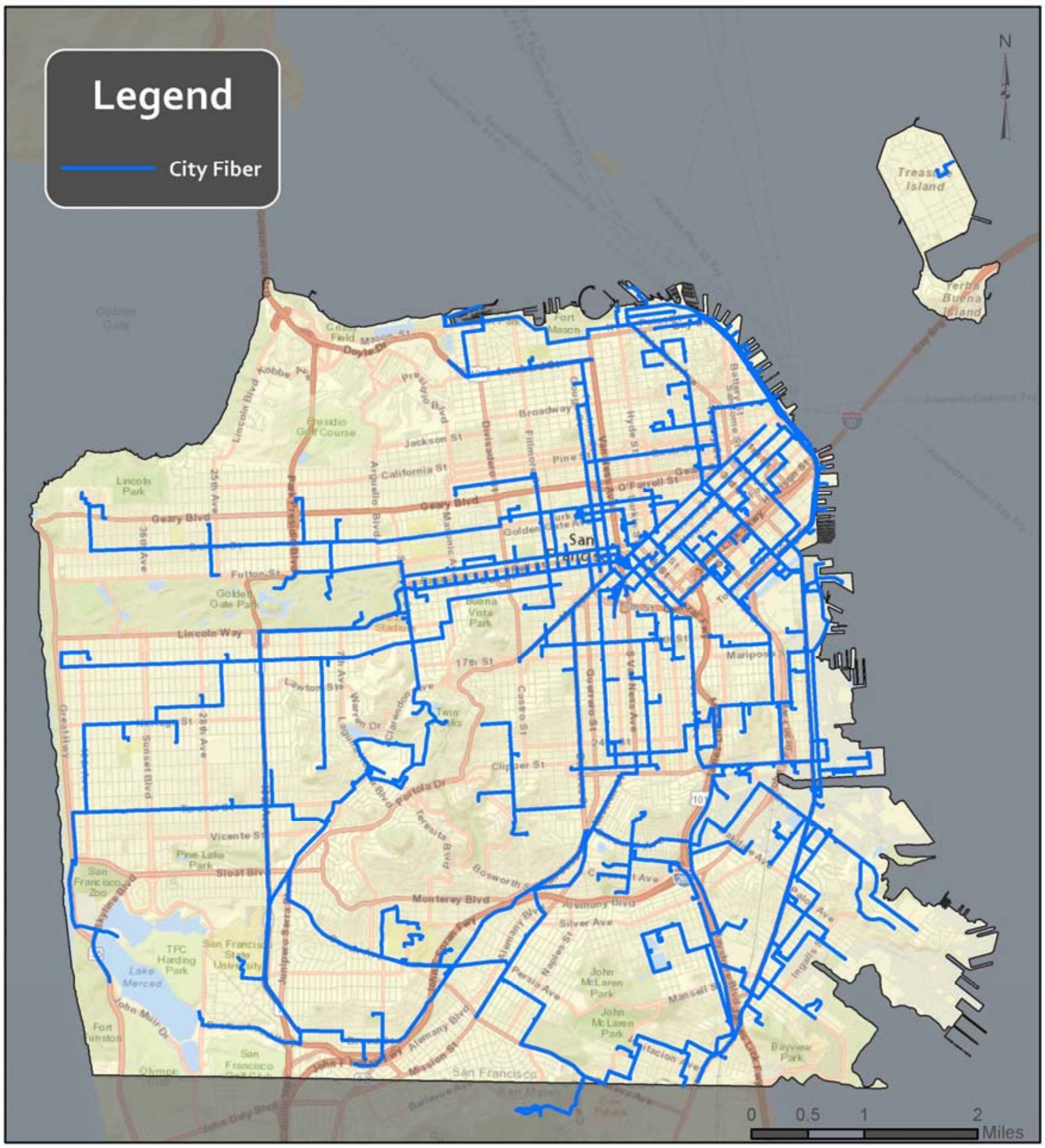
#2	**Conduit Information**
Specific information on the provider's available conduit would provide additional benefit. Useful data would include the following: • Conduit size • Current occupancy and available space • Access points (i.e. handhole locations, building entrances) • Information on the terms and conditions to include any applicable service restrictions • Per foot pricing for leased conduit Provider may have some of the conduit attributes in GIS format which would be preferred, though it is more likely they have paper records of this information.	

Appendix G: Potentially Usable City Facilities

City-Owned Fiber Infrastructure

The City's existing fiber infrastructure has potential to be used for this project. The infrastructure comprises conduit, handholes, and pole attachments which are all built to accommodate fiber deployment. As an example, the project could leverage additional conduit space in the existing underground fiber routes to reduce construction costs. In areas where the City has aerial fiber, new fiber can be overlashed to the City attachments instead of requiring a new attachment, which may reduce or eliminate make-ready work.

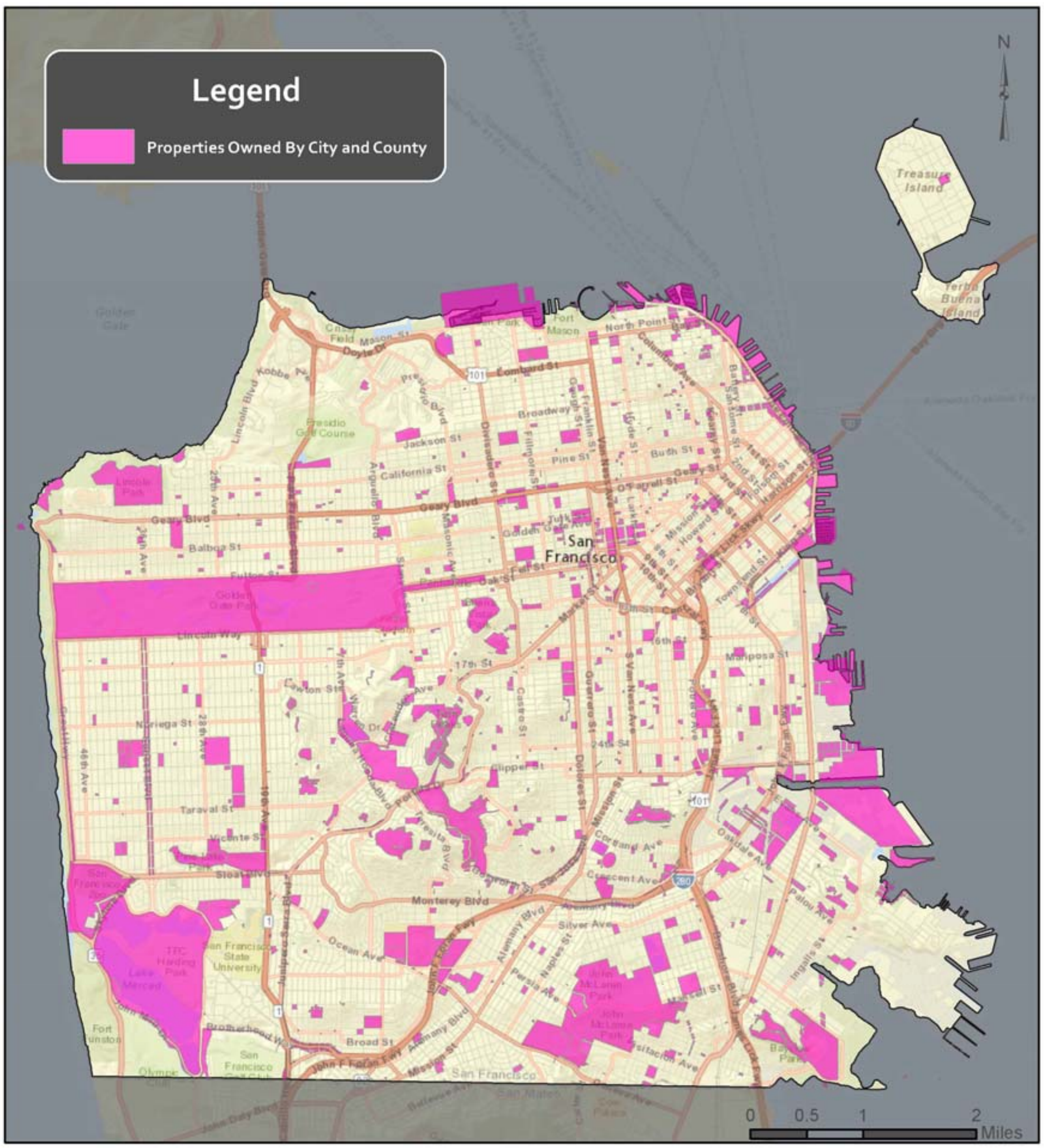
Figure 17: City Fiber Facilities



City-Owned Property

City property can provide a place to locate network hub sites, fiber distribution cabinets, or other infrastructure. The sample design estimates the need for approximately 10 hub locations spread throughout the City. Each hub will require approximately 200 feet of space, power, secure access, and environmental controls. The hubs can be placed in buildings that meet these requirements, or in telecom huts built on City property. Fiber distribution cabinets are much smaller than hubs and can be placed in the ROW or be mounted on utility poles. However, it may be ideal to place the cabinets on City property when feasible to keep the ROW clear of additional congestion.

Figure 18: Property Owned by City and County



Appendix H: Digital Inclusion and Broadband Affordability

The Fiber for San Francisco Initiative is intended to develop new means of expanding next-generation, world-class broadband infrastructure in the City. The following is an analysis of some considerations regarding digital inclusion in the City.

This section notes that affordability is one critical challenge in ensuring the universal adoption of broadband services, despite the apparent universal availability of fixed and mobile broadband in San Francisco, in part because of the uneven availability of lower-priced products that are ostensibly targeted toward low-income residents of the City. Affordability of broadband services is by no means the only factor impacting adoption rates, but addressing that issue is one way that the City can improve rates of use of high-speed broadband by lower-income members of the community. Complementary initiatives focused on device ownership and internet literacy will be necessary to supplement the City's efforts to make high-speed broadband affordable.

Low Broadband Adoption in San Francisco Correlates with Lower-Income Areas

Recent data from the FCC suggests a correlation between lower broadband adoption rates and lower-income areas in the City. While the data do not speak to causation, the correlation is important when considering barriers to broadband adoption.

Twice a year, internet service providers (ISPs) submit data to the FCC via Form 477, reporting where wireline broadband service is available and the percent of households subscribing to their service.[104] This information is then aggregated by the FCC and released to the public roughly one year after collection. The data illustrate the percentage of homes with minimum internet speeds within a given census tract.

Census tracts are defined by geographical boundaries (rather than population), and can contain from 1,200 to 8,000 people.[105] As a result, it is impossible to obtain a definitive number of how many households subscribe to internet services from Form 477 data. Rather, the most recent available data (from December 31, 2015) show the percent of households receiving a service of a minimum 200 Kbps one-way, and a minimum 10 Mbps/1 Mbps (upstream/downstream) within 196 census tracts in the City.

Table 32 provides a breakdown of census tracts by percent subscription rate.[106]

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[104] Entities required to submit these data include "facilities-based providers of broadband connections" and "providers of wired or fixed wireless local exchange telephone service." *See:* "Who Must File Form 477?", Federal Communications Commission, https://transition.fcc.gov/form477/WhoMustFileForm477.pdf (accessed March 2017).

[105] "Geographic Terms and Concepts – Census Tract," U.S. Census Bureau, https://www.census.gov/geo/reference/gtc/gtc_ct.html (accessed March 2017).

[106] "Internet Access Service Reports," Federal Communications Commission, https://www.fcc.gov/reports-research/reports/internet-access-services-reports/internet-access-services-reports (accessed March 2017).

Table 32: Number of Census Tracts by Subscription Rate

Percent of Households	Census Tracts with Minimum 200 Kbps One-Way	Census Tracts with 10 Mbps Upstream/ 1 Mbps Downstream
0	1	1
1 to 20%	0	2
21 to 40%	4	4
41-60%	4	37
61-80%	44	130
81%+	143	22

The majority of census tracts have a subscription rate of 80 percent or above for minimum 200 Kbps service, and a 60 to 80 percent subscription rate for minimum 10 Mbps/1 Mbps. While these adoption rates are slightly higher than the nationwide average,[107] it should be noted that neither of these speeds meet the current FCC definition of broadband, which is 25 Mbps/3 Mbps.[108]

When superimposed over a map of the City, the data illustrate the geographical areas with lower subscription rates. Figure 19 shows 200 Kbps adoption rates by census tract,[109] and Figure 20 shows 10 Mbps/1 Mbps adoption rates by census tract.[110] In these maps, dark blue represents areas with higher adoption rates, while light blue and white represent areas with lower adoption rates.

[107] "report_dec_2015_body_17NOV16.doc,," downloaded file, Federal Communications Commission, https://www.fcc.gov/file/11764/download (accessed March 2017).
[108] "2015 Broadband Progress Report and Notice of Inquiry on Immediate Action to Accelerate Deployment," Federal Communications Commission, January 29, 2015 (adopted), https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-10A1.pdf (accessed March 2017).
[109] "Form 477 Census Tract Data on Internet Access Services," Federal Communications Commission, https://www.fcc.gov/general/form-477-census-tract-data-internet-access-services (accessed March 2017).
[110] Ibid.

Figure 19: Percent of Households with Minimum 200 Kbps Service

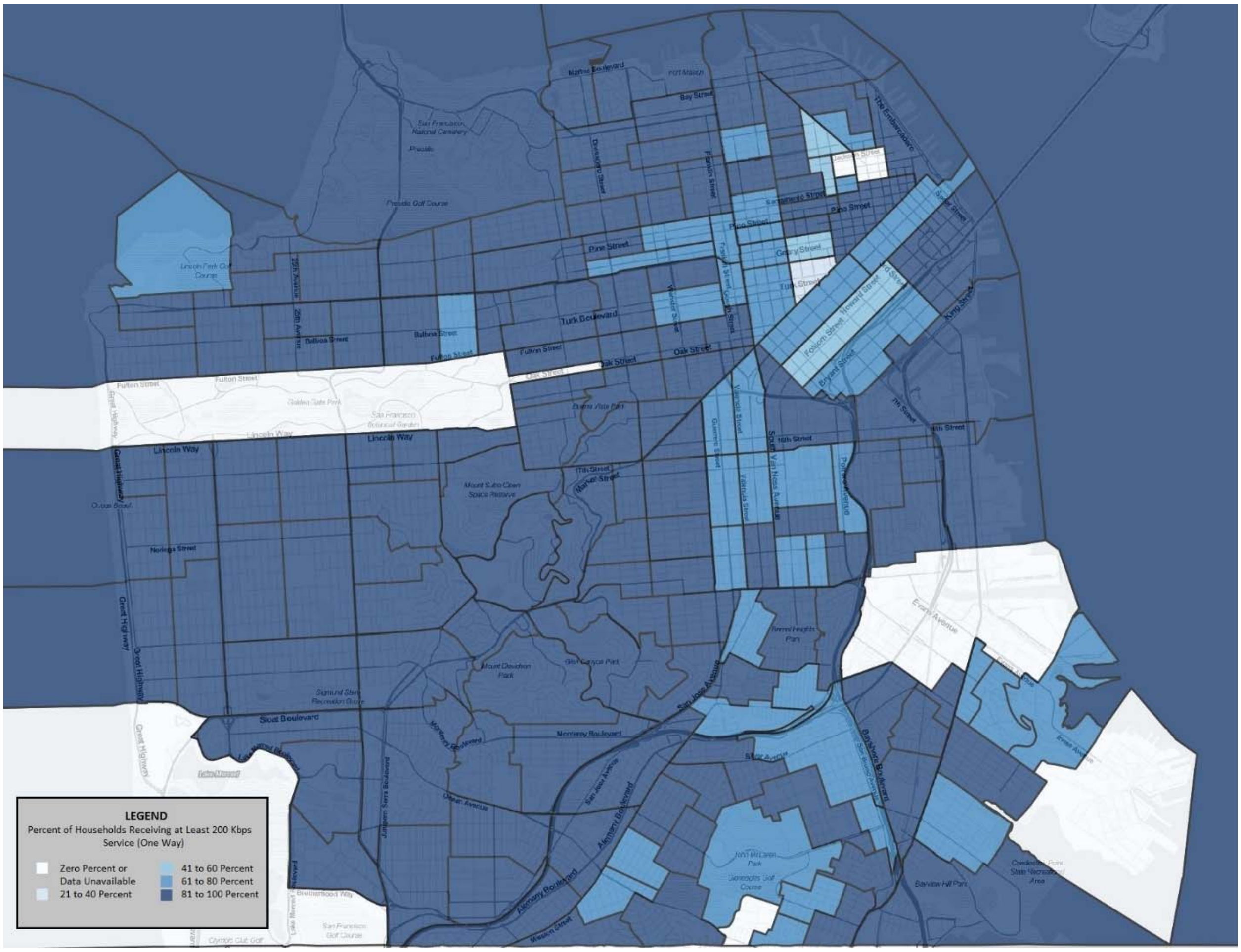
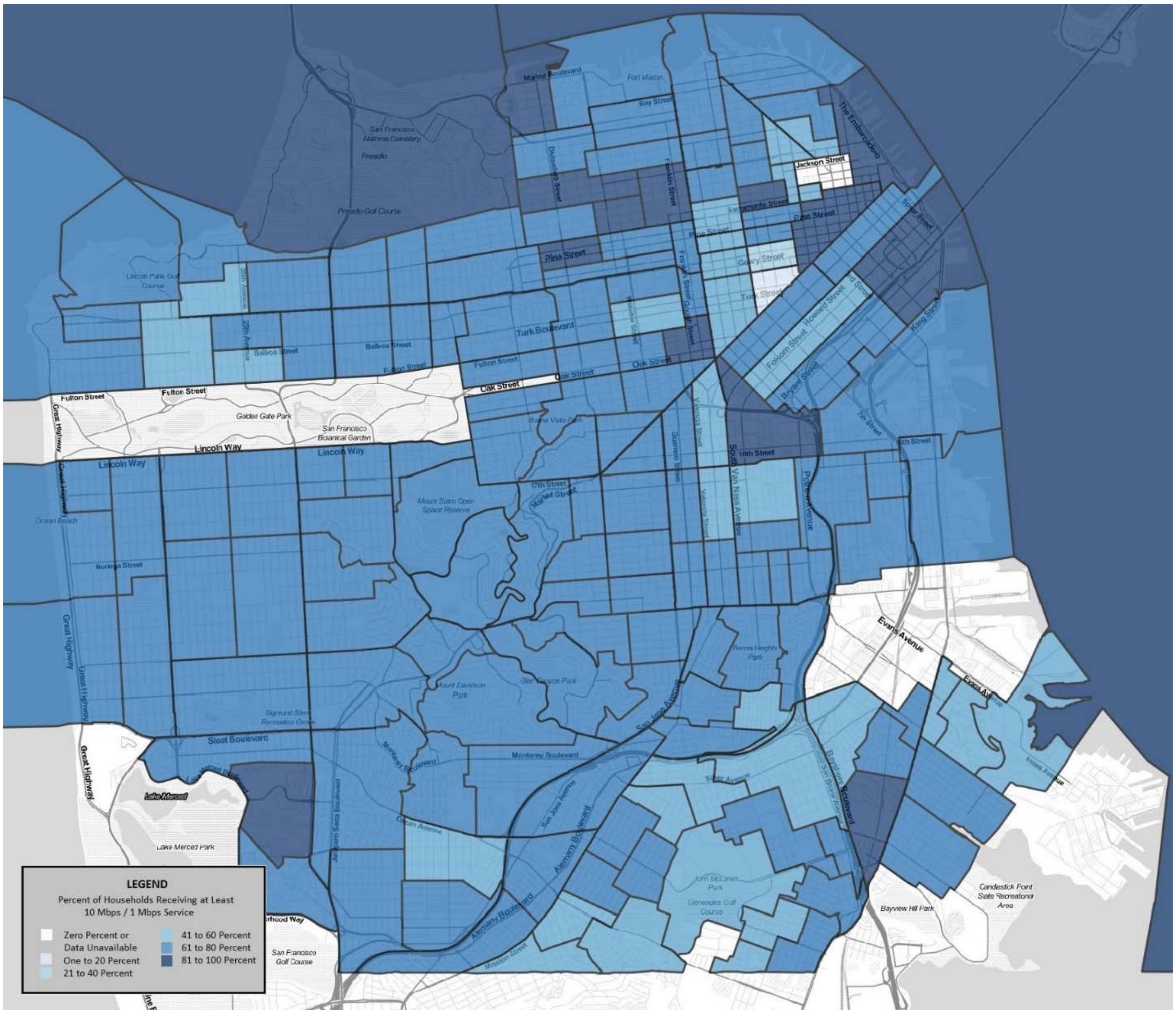


Figure 20: Percent of Households with Minimum 10 Mbps/1 Mbps Service



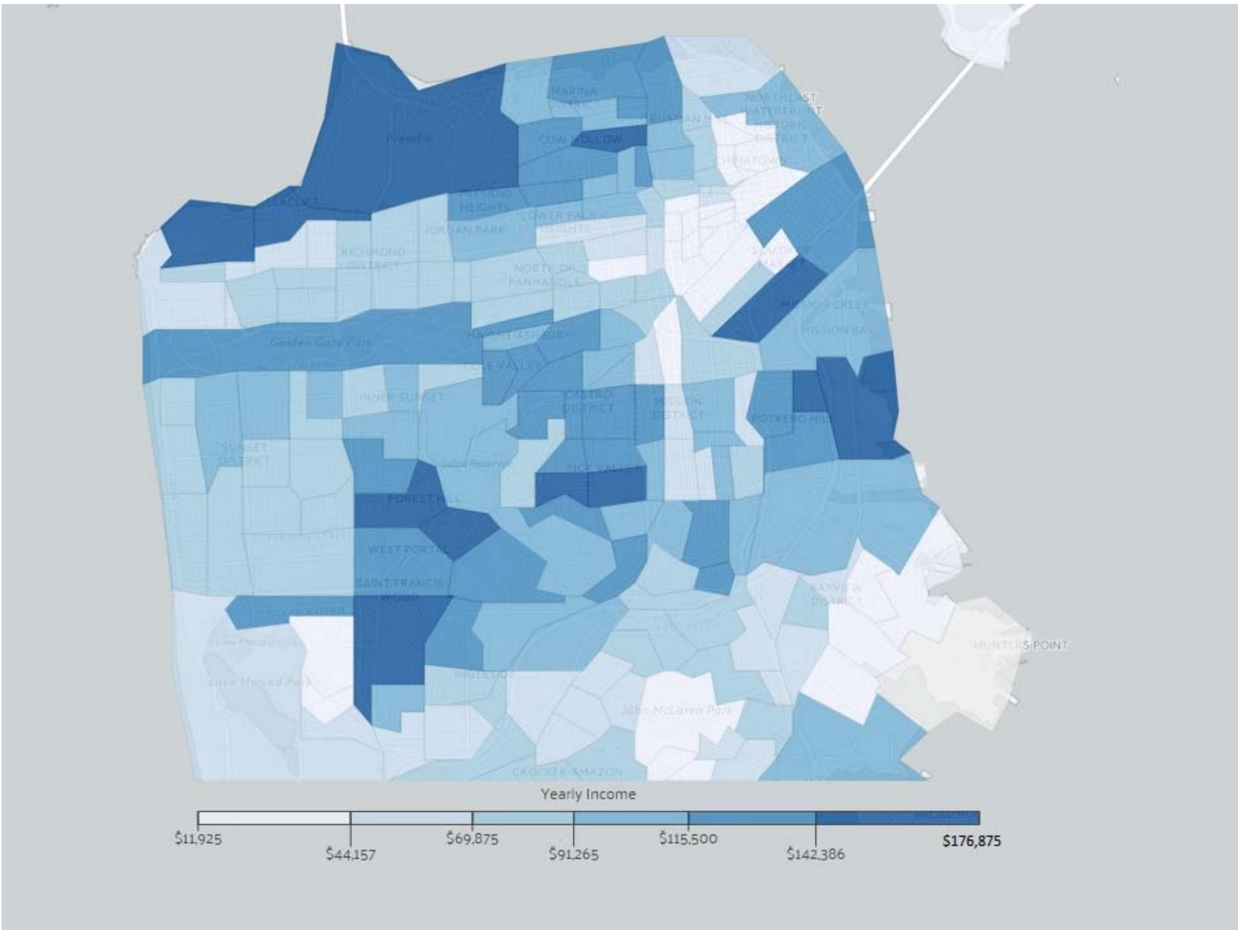
In both figures, the map shows a clear crescent-shaped area of lower subscription rates, passing from the area north of Chinatown, through the Mission district, and then back southeast to the Bayview district. There is also a pocket of low subscription in census tracts in the south of the City.

Figure 21 illustrates census tracts by yearly household income, with dark blue representing higher average household income.[111] This map illustrates the same crescent shape and southern pocket—an illustration of low-income areas that correlates with low broadband adoption illustrated in Figure 20. The clear commonalities of the geographic distribution in the two data

[111] Data USA, https://embed.datausa.io/profile/geo/san-francisco-ca/economy/income_geo/?viz=True (accessed March 2017).

sets demonstrate that areas of the City with low household income also have lower subscription rates.

Figure 21: Yearly Household Income by Census Tract



Cost Is Among the Key Factors Driving Lower Internet Adoption Rates Nationally

With 13.2 percent of the City's residents living below the poverty level,[112] affordability of broadband services remains a significant factor in the City's digital inclusion efforts. For many American households that have not adopted broadband services, decisions regarding internet access "are often a choice between having internet service and having food."[113] In a 2015 Pew Research Center survey, 33 percent of respondents who did not have internet access at home cited the high cost of service as the main reason.[114]

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[112] "Quick Facts: San Francisco County, California; San Francisco city, California," U.S. Census Bureau, Data as of July 1, 2016, https://www.census.gov/quickfacts/table/PST045216/06075,0667000 (accessed March 2017).
[113] Colin Rhinesmith, Digital Inclusion and Meaningful Broadband Adoption Initiatives," *Benton Foundation,* January 2016, https://www.benton.org/sites/default/files/broadbandinclusion.pdf (accessed March 2017).
[114] "Home Broadband 2015," Pew Research Center, December 21, 2015, http://www.pewinternet.org/2015/12/21/home-broadband-2015 (accessed March 2017).

Although the digital divide has narrowed over the course of the last decade, many low-income individuals remain unable to access the internet from home, hindering their ability to reach economic and educational resources critical for success in the 21st century. According to a recent Pew Research Center survey, 47 percent of Americans with household incomes under $30,000 per year lack home broadband service, compared with 6 percent among individuals with household incomes over $100,000 per year.[115]

The City analyzed digital divide issues in 2007 and again in 2015. In the latter study, the Board of Supervisor's budget and legislative analyst reported on a study that found that 12 percent of City residents lack internet access at home (and another 6 percent reported using dial-up connections). While the study noted that "75 percent of households with incomes of less than $25,000" had home internet access—a significantly higher percentage of low-income residents than the national average—affordability is still clearly an issue.[116] The 2007 study also indicated that affordability was a factor in home internet use.[117]

While these numbers are better than the national numbers, there is still, as of the date of these studies, a remarkable gap between lower- and higher-income residents of the City in terms of home internet use. Despite the barriers, each year more and more low-income individuals are finding ways to access online resources. As of 2016, 79 percent of adults living with household incomes under $30,000 reported using the internet[118] and 64 percent reported having a smartphone.[119] Even those without home broadband service increasingly acknowledge that access to the internet is critical in many key areas of life.[120]

[115] Monica Anderson, "Digital divide persists even as lower income Americans make gains in tech adoption," *Pew Research Center,* March 22, 2017, http://www.pewresearch.org/fact-tank/2017/03/22/digital-divide-persists-even-as-lower-income-americans-make-gains-in-tech-adoption/ (accessed March, 2017).
[116] Fred Brousseau, "Policy Analysis Report: Digital Divide in San Francisco," City and County of San Francisco Board of Supervisors, April 15, 2015, http://sfbos.org/sites/default/files/FileCenter/Documents/52249-BLA.DigitalDivide.041515.pdf (accessed March 2017).
[117] Thomas Berman, Matthew Case, Joshua Daniels, Mara Larsen-Fleming, and Sun Ha Lee, "Digital Inclusion in San Francisco," University of California, Berkeley, and San Francisco Department of Telecommunications and Information Services, June 2007, http://sfgov.org/dt/ftp/uploadedfiles/dtis/tech_connect/UCBDigitalInclusionReport060282007Final%281%29.pdf (accessed March 2017).
[118] "Internet/Broadband Fact sheet," Pew Research Center, January 12, 2017, http://www.pewinternet.org/fact-sheet/internet-broadband/ (accessed March 2017).
[119] Monica Anderson, "Digital divide persists even as lower income Americans make gains in tech adoption," Pew Research Center, March 22, 2017, http://www.pewresearch.org/fact-tank/2017/03/22/digital-divide-persists-even-as-lower-income-americans-make-gains-in-tech-adoption/ (accessed March 2017).
[120] John Horrigan and Maeve Duggan, "Home Broadband 2015," Pew Research Center, December 21, 2015, http://www.pewinternet.org/2015/12/21/home-broadband-2015/pi-2015-10-21_broadband2015-03/ (accessed March 2017).

For those who lack home internet, some make use of free broadband services at libraries, community centers, and private businesses, while others rely on their mobile devices. Roughly one-fifth of individuals living with household incomes under $30,000 report having a smartphone, but no internet at home, up from 12 percent in 2013.[121] With few other options, low-income households disproportionally rely on smartphones to complete tasks that wealthier counterparts complete on laptops and desktops. The majority of low-income smartphone owners report using their mobile device to look up information about a job, and a third report using their smartphone to send in job applications.[122]

So as the internet becomes increasingly relevant to the lives of low-income individuals, what keeps them from signing up for home broadband service? While no single factor can explain the persistent home broadband gap, the high cost of monthly subscriptions is undoubtedly a major contributor. When individuals without home broadband were asked their most important reason for not having a home broadband connection, 33 percent said that monthly home broadband subscriptions are too expensive, more than twice the response that any other reason received.[123]

A recent study of broadband adoption initiatives found that, while all low-income individuals and families who participated in this study understood the value of broadband connectivity, many were often forced to choose between having internet and having enough food for the month.[124] In a study of individuals who have dropped home broadband service, all individuals with household income up to $40,000 per year cited the service being "too expensive" as the primary reason why they dropped service.[125]

Broadband Service Costs in San Francisco Are Unevenly Distributed, Unpredictable, and, for Some, Unaffordable

Current data products available in the City reflect unpredictable layers of cost.

[121] Monica Anderson, "Digital divide persists even as lower income Americans make gains in tech adoption," *Pew Research Center,* March 22, 2017, http://www.pewresearch.org/fact-tank/2017/03/22/digital-divide-persists-even-as-lower-income-americans-make-gains-in-tech-adoption/ (accessed March 2017).

[122] Aaron Smith, "U.S. Smartphone Use in 2015," Pew Research Center, April 1, 2015, http://www.pewinternet.org/2015/04/01/chapter-two-usage-and-attitudes-toward-smartphones/#job percent20seeking (accessed March 2017).

[123] John Horrigan and Maeve Duggan, "Home Broadband 2015," Pew Research Center, December 21, 2015, http://www.pewinternet.org/2015/12/21/home-broadband-2015/pi-2015-10-21_broadband2015-12/ (accessed March 2017).

[124] Colin Rhinesmith, Digital Inclusion and Meaningful Broadband Adoption Initiatives," Benton Foundation, January 2016, https://www.benton.org/sites/default/files/broadbandinclusion.pdf (accessed March 2017).

[125] Brian Whitacre and Colin Rhinesmith, "Understanding Broadband Un-adopters," Benton Foundation, January 12, 2016, https://www.benton.org/blog/understanding-broadband-un-adopters (accessed March 2017).

Wireline Data Products

Comcast advertises no-contract residential internet services with 25 Mbps maximum download speed for $49.99 per month. While its advertised price alone may be prohibitive to low-income citizens, the plan comes with further hidden charges:

- Activation fee up to $500 (total price not disclosed until after sign up)
- Promotional price increases to $59.99—$64.99 per month after first year (total price not disclosed until after first year)
- Plan subject to early termination fee (price not disclosed)
- Plan price does not include equipment charges, which can be either a substantial upfront cost, or monthly "nominal fees"
- Plan allows 1 TB of data use per month, after which each 50 GB increment will cost $10 per month (not to exceed $200 monthly)
- All fees, other than the contracted monthly subscription fee, are subject to change at any time[126]

In the first month of service alone, pricing stipulations of at least $500 in costs additional to service fee are likely to serve as obvious barriers to adoption by low-income residents.

Mobile Wireless Data Products

For subscribers who do not purchase wireline data services at home, data-only mobile broadband services provided by major wireless carriers are a potential alternative. However, the high cost of connectivity and adequate capacity can prove to be deterrents to even moderate-income subscribers. Similar to their wired counterparts, mobile broadband plans are frequently rife with upcharges and unexpected costs. Unlike most wired plans, many mobile services charge by the amount of data transmitted, limiting their feasibility for high-capacity applications such as transmission of large files, videoconferencing, and extended content and media-rich web browsing.

The cost of an entry-level mobile data product from Verizon begins at $20 per month for 2 GB of data. Prices increase $10 per month per 2 GB additional data. Further charges include:

- $5 per month per device connected to the plan
- $10 per month per tablet connected to the plan

[126] "Select the package that's perfect for you," Comcast Xfinity, https://www.xfinity.com/locations/internet-service/california/sanfrancisco.html (accessed March 2017).

- $20 per month per hotspot connected to the plan
- $15 per each additional 1 GB of data
- Cost of device, tablet, or hotspot

Subscribers who do not want to be charged overage fees can choose to be "throttled" once plan data allowances have been used, slowing connection speeds to 128 Kbps—well below broadband speeds, and limiting functionality.[127]

AT&T also offers wireless internet plans, characterized by high price points and a limited amount of "high-speed" data. For those interested in a data-only plan, AT&T has a 250 MB plan for $14.99 monthly, which includes unlimited access to AT&T Wi-Fi hotspots distributed around major metropolitan areas. This plan does not allow customers to "tether" another device, so all browsing must occur on the mobile device on the plan. If the customer exceeds the 250 MB allowance, each additional 250 MB used costs an additional $14.99. Higher-capacity 3 GB and 5 GB plans can be purchased for $30 and $50 per month, respectively, and come with similar overage fees. For customers who wish to "tether" another device (such as a home computer, an additional tablet, or phone other than that on the plan), customers must purchase the $50 plan.[128]

Recently, AT&T announced an "unlimited" plan that includes unlimited talk, text, and data. For $90 per month, the plan allows 22 GB of data at 4G-LTE speeds, after which AT&T throttles the user to 128 Kbps. For those interested in tethering their home computer or another device to this plan, only 10 GB of the initial 22 GB will be 4G-LTE speeds for tethering or "mobile hotspot" use. Like the above plans, the advertised price is lower than the amount customers will be charged in the first few months. To receive $90 monthly pricing, customers must enroll in autopay (with a credit card), paperless billing, and allow "1—3 months" of billing cycles before discounts will be applied.[129] Given these constraints, this product may not be useful for lower income San Franciscans.

T-Mobile also offers prepaid mobile, data-only plans for customers who lack sufficient credit to qualify for monthly plans, or who do not wish to sign up for multi-year contracts. T-Mobile's pay-as-you-go plan costs $3 per month, but customers then must regularly purchase data passes at a rate of $5 per day inclusive of 500 MB of 4G data, or $10 per week for 1 GB of 4G data.[130] The

[127] "Data Only Plan," Verizon Wireless, https://www.verizonwireless.com/plans/data-only-plan (accessed March 2017).
[128] "Select a Plan," AT&T, https://www.att.com/shop/wireless/plans/planconfigurator.html (accessed March 2017).
[129] "Unlimited Data. Unreal Deal," AT&T, https://www.att.com/plans/unlimited-data-plans.html (accessed March 2017).
[130] "Pay As You Go," T-Mobile, https://prepaid-phones.t-mobile.com/pay-as-you-go (accessed April 2017).

company also offers monthly prepaid plans at a rate of $45 per month for 4 GB of 4G data, $55 per month for 6 GB of 4G data or $75 for unlimited 4G data.[131] However, the unlimited plan's fine print contains a number of restrictions, including an additional $15 tethering fee for every 5 GB of 4G data used on tethered devices.[132]

Sprint has prepaid 3G/4G (depending on availability) mobile data plans as well, ranging from $15 per day inclusive of 150 MB of data, $30 per week inclusive of 500 MB of data, and $50 per month inclusive of 1.5 GB of data.[133] They also have a post-paid unlimited plan for $60 per month, but it requires a credit check, and once again, the unlimited plans come with a number of restrictions in the fine print, including a 10 GB limit on tethered data use.[134]

AT&T, T-Mobile, and Sprint also have their own prepaid brands that market themselves to lower-income customers. AT&T's Cricket Wireless offers monthly plans at a rate of $30 for 1 GB, $40 for 3 GB, $50 for 8 GB, and $60 for unlimited data (throttled after 22 GB); however, these plans are restricted to 8 Mbps when a user is on AT&T's 4G LTE network, and to 4 Mbps when on AT&T's HSPA+ network.[135]

T-Mobile's MetroPCS offers monthly plans at a rate of $30 for 1 GB, $40 for 3 GB, $50 for unlimited LTE data on a single handset, and $60 for unlimited LTE data on a single handset plus 8 GB of tethered data.[136]

MetroPCS customers enjoy speeds close to the speeds of T-Mobile customers. In a recent test, MetroPCS boasted an average download speed of 22 Mbps and upload speed of 16 Mbps.[137] Sprint has two prepaid brands, Virgin Mobile USA and Boost Mobile. Virgin Mobile has monthly plans priced at $35 for 5 GB of 4G LTE data and $45 for 10 GB, with each additional GB of data costing $5. Boost Mobile offers a $35 monthly plan with 2 GB of data, with each additional GB of

[131] "Prepaid Phones," T-Mobile, https://prepaid-phones.t-mobile.com/prepaid-plans-individual?icid=WEB_Q117PREPAI_YYP087QVHNJ7801#getting-started (accessed April 2017).

[132] Jacob Kastrenakes, "T-Mobile and Sprint's new unlimited plans have some nasty fine print," *The Verge*, August 18, 2016, http://www.theverge.com/2016/8/18/12533308/tmobile-sprint-unlimited-data-plans-limit-video (accessed April 2017).

[133] "Services," Sprint, http://shop.sprint.com/mysprint/services_solutions/details.jsp?detId=mbb_passes&catId=service_mbb&catName=Mobile%20Broadband&detName=Mobile%20Broadband%20Passes&specialCat= (accessed April 2017).

[134] "Unlimited," Sprint, https://www.sprint.com/landings/unlimited-cell-phone-plans/ (accessed April 2017).

[135] "Plans," Cricket, https://www.cricketwireless.com/support/plans-and-features/cricket-plans-and-features/customer/plans.html (accessed April 2017).

[136] "Plans," MetroPCS, https://www.metropcs.com/shop/plans (accessed April 2017).

[137] Philip Michaels, "MetroPCS Is Fastest Discount Carrier, Straight Talk Slowest," *Tom's Guide*, March 28, 2017, http://www.tomsguide.com/us/discount-carriers-performance,news-24762.html (accessed April 2017).

data costing $5. It also has an unlimited plan for $50 per month, but again, tethering is limited to 8 GB of data.[138]

In addition to the four major carriers, there are a number of mobile virtual network operators (MVNOs) that offer low-cost, no contract, data plans. Google's Project Fi offers a $20 per month plan, where customers pay $10 per GB of data they use.[139] Ting Mobile offers plans under which consumers pay only for as many voice minutes, texts, and GB of data as they use each month, with a $6 per line base rate and each GB of data used costing $10.[140] Republic Wireless has monthly plans that offer unlimited voice minutes and texts at a rate of $20 for 1 GB, $30 for 2 GB, $45 for 4 GB, and $60 for 6 GB of cellular data.[141] These MVNOs rely on partnership agreements with major carriers, and therefore speeds and availability are dependent on the strength of their partner carrier's network in a given area. Given that much of the new investment in high speed mobile networks is concentrated in high-income areas, individuals living in lower-income neighborhoods have access to slower than average service speeds.

Mobile Broadband Services Represent an Inadequate Alternative to Fixed Services

While mobile data plans may be helping to bridge the divide for now, they have distinct disadvantages compared to wired broadband subscriptions. Low-cost mobile data plans are often metered, with strict data caps. Thrifty mobile users learn to wait until they are connected to Wi-Fi to download large files, or use data-intensive applications, such as video-streaming or teleconferencing. Those who live with, or in close proximity to available Wi-Fi networks can pay substantially less for mobile data than someone who uses the same amount of data, but relies exclusively on their mobile carrier's network.

The demand for mobile data is skyrocketing,[142] and in many areas, carriers are struggling to keep up.[143] If the federal government fails to free up substantial amounts of new spectrum in the next few years, the U.S. could face a serious shortage of spectrum available for commercial data

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138 "Shop Plans," Boost Mobile, https://www.boostmobile.com/#!/shop/plans/monthly-phone-plans/ (accessed April 2017).

139 "Project Fi: A simple plan for everyone," Google, https://fi.google.com/about/plan/ (accessed April 2017.)

140 "Only pay for the levels you reach," Ting, https://ting.com/rates (accessed April 2017).

141 "Smartphone service shouldn't have to cost a lot. Now it doesn't." Republic Wireless, https://republicwireless.com/cell-phone-plans/?gclid=CjwKEAjwq5LHBRCN0YLf9-GyywYSJAAhOw6mWSuShk9jtYZlI_se8gHqgH3j82ex7MXUonHIli0wOBoCvZbw_wcB (accessed April 2017).

142 Phillip Tracy, "Moving in-building forward with shared infrastructure and neutral host," *RCR Wireless News,* November 1, 2016, http://www.rcrwireless.com/20161101/carriers/in-building-neutral-host-tag31

143 Keith Carls, "Next Generation Cell Tower Coming to Area Near You; cellular companies scrambling to keep up with demand from mobile devices," *KEYT,* May 25, 2016 http://www.keyt.com/news/santa-barbara-s-county/next-generation-cell-towers-coming-to-area-near-you/87615564 (accessed March 2017).

services, which would lead to slow downs and price spikes.[144] Even if an individual purchases high-speed service or an unlimited plan, many of the major carriers' terms of service contain fine print allowing the carriers to throttle speeds during periods of network congestion, or after a customer reaches a certain usage milestone each month. Most of the unlimited plans have strict limits on how much data tethered devices can use, making them less-than ideal for use as a households primary internet connection.[145]

Lower-Cost Broadband Services Are Not Universally Available and Tend to Offer Lower Speeds

Comcast Internet Essentials

For some low-income and senior households that meet very specific requirements, Comcast offers its Internet Essentials service for $9.95 per month. The service includes up to 10 Mbps download speeds, and advertises no contract or installation fees necessary. To be eligible for the service, all applicants must meet all the following eligibility requirements:

- Live in an area currently served by Comcast,
- Not have been a Comcast internet subscriber within the past 90 days, and
- Have no outstanding debt to Comcast from within the past year[146]

All families with students enrolled in schools with more than 40 percent of the student body participating in the National School Lunch Program's free or reduced lunch program are automatically approved for the program and do not need to submit individual documentation beyond certifying that a child is enrolled in a pre-approved school.[147]

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[144] George Ford, "Have we got it all wrong? Forecasting mobile data use and spectrum exhaust," *Phoenix Center for Advanced Legal & Economic Public Policy Studies,* October 21, 2014, http://www.phoenix-center.org/perspectives/Perspective14-06Final.pdf (accessed March 2017).

[145] Tim Moynihan, "Verizon's Unlimited Plan is Back. Here's how it compares to other carriers," *Wired,* February 13, 2017, https://www.wired.com/2017/02/verizons-unlimited-data-plan-back-heres-compares-carriers/; Christina Warren, "Is Verizon's resurrected Unlimited data plan a good deal?" *Gizmodo*, February 13, 2017, http://gizmodo.com/is-verizons-resurrected-unlimited-data-plan-a-good-deal-1792294971; Jon Brodkin, "T-Mobile now throttling mobile hotspots when network is congested," *ArsTechnica, October 4, 2016,* https://arstechnica.com/information-technology/2016/10/t-mobile-now-throttling-mobile-hotspots-when-network-is-congested/; Adam Ismail, "Cricket's Unlimited data customers could soon see speed cuts during peak hours," *Digital Trends,* February 27, 2017, http://www.digitaltrends.com/mobile/cricket-reduces-unlimited-data-speeds/ (accessed March 2017).

[146] "Affordable Internet at home for your family," Internet Essentials from Comcast, https://www.internetessentials.com/apply (accessed March 2017).

[147] "Internet Essentials from Comcast," Fact Sheet, Comcast, August 2016, https://www.internetessentials.com/~/media/InternetEssential/IE%20Fact%20Sheet%209.9.2016.pdf (accessed April 2017).

Households that do not meet the pre-approved criteria must demonstrate financial eligibility by submitting proof that:

- At least one child is eligible for the Federal School Lunch Program,
- At least one member of the household is eligible for the Supplemental Nutrition Assistance Program (SNAP) or
- At least one member of the household is eligible for Housing and Urban Development (HUD) assistance.[148]

In addition, seniors in select pilot areas, including San Francisco, are eligible for the program, provided they are older than 62, and are receiving state or federal assistance.[149] Community college students enrolled in select public post-secondary educational institutions in Colorado and Illinois that are Pell Grant recipients are also eligible for the program.[150] Comcast has not announced plans to expand these pilot programs at this time.

It should be noted that while the Internet Essentials program is an indisputable step in the right direction, its limited scope in assisting only those on federal assistance programs may be leaving behind those in the lower income brackets who do not qualify for federal help. For many Americans who do not qualify for federal assistance, the choice between food and internet may be an obvious, though difficult decision.

And despite the availability of Internet Essentials, the City's Budget and Legislative Analyst found in 2015 that although 70 percent of public school students in the City's public schools (approximately 11,000 student families) are eligible for the program, only approximately 1,500 students (13.6 percent) do subscribe.[151]

AT&T Access

AT&T also offers a low-cost product for lower-income consumers. As one of the conditions of AT&T's merger with DirecTV, AT&T agreed to offer low-cost wireline home internet service for low-income individuals and households. The company's "Access" service is available to households living in AT&T's existing service area in which at least one resident participates in the Supplemental Nutrition Assistance Program (SNAP) program. The program is also open to

[148] "Frequently Asked Questions: Housing Assistance," Internet Essentials from Comcast, https://www.internetessentials.com/Getting-Help/HousingAssistance (accessed March 2017).
[149] "Frequently Asked Questions: Seniors," Internet Essentials from Comcast, https://www.internetessentials.com/Getting-Help/Seniors (accessed March 2017).
[150] "Access to school and job opportunities, now from home," Internet Essentials from Comcast, https://www.internetessentials.com/college (accessed April 2017).
[151] City and County of San Francisco Board of Supervisors Budget and Legislative Analyst, Policy Analysis Report regarding Digital Divide in San Francisco, April 15, 2015.

Californians receiving Supplemental Security Income (SSI) benefits. Further requirements include:

- Home address in a currently served area within AT&T's 21-state footprint
- No outstanding debt for standard AT&T internet service within the past 6 months
- No outstanding debt for Access service

AT&T provides qualifying individuals with speeds ranging from 768 Kbps to 10 Mbps, depending on availability. Service levels between 768 Kbps and 3 Mbps cost $5 per month, while the 5 to 10 Mbps service costs $10 per month. For qualifying individuals, the service contains no start-up or installation fees, and includes a Wi-Fi router for the home. Customers also receive access to AT&T's network of hotspots. Like other wired plans, Access plans are subject to a data cap of 150 GB for $5 plans and 1 TB for $10 plans, and overages will be charged $10 per 50 GB over plan limits.[152]

The Access service will only remain available until 2020.[153]

Initially, AT&T used a loophole in the merger condition to offer the discounted Access service only in locations where its network could support 3 Mbps service, regardless of eligibility.[154] After some controversy, the company has since expanded the program to those living in areas with at least 768 Kbps service available. Individuals living in areas where 768 Kbps is not available still cannot qualify for service through Access.

Federal Lifeline Subsidy

Low-income residents may be able to obtain a service subsidy through the federal Lifeline program, which offers benefits for either telephone or internet service to qualifying low-income households nationwide, effectively providing low- or no-cost telephone or internet service. For a household to be eligible for the program, a member must be enrolled in one of nine federal aid programs, including the Supplemental Nutrition Assistance Program (SNAP), Supplemental Security Income (SSI), and Medicaid; or have a household income below the Federal Poverty

[152] "Access from AT&T," https://www.att.com/shop/internet/access/#/ (accessed March 2017).
[153] "Access from AT&T," https://www.att.com/shop/internet/access/#/ (accessed March 2017).
[154] Jon Brodkin, "AT&T refuses to offer low-income discounts for sub-3Mbps Internet," *ArsTechnica*, September 6, 2016, https://arstechnica.com/information-technology/2016/09/att-refuses-to-offer-low-income-discounts-for-sub-3mbps-internet/ (accessed March 2017).

guideline. Households are eligible for one benefit—either telephone or internet service—usually totaling a $9.25 credit on their monthly bill.[155]

To apply, new customers petition qualified Lifeline providers (of which there are 36 in California, including AT&T for home phone service, but not any of the City's other providers[156]) and provide documentation of eligibility for the program. The providers then check applicants' eligibility against the registries of federal programs, and if accepted, receive funds for each eligible subscriber from the Universal Service Fund, managed by the Universal Services Administrative Company.[157] Once subscribed, Lifeline customers may change providers once every 60 days for telephone service, or once every 12 months for internet service.[158]

Recent political changes have created threats to the program. In February, FCC Chairman Ajit Pai announced that nine potential Lifeline providers would not be allowed to participate in the Lifeline program,[159] despite their earlier certification by the FCC under former Chairman Tom Wheeler. Wheeler's former advisor Gigi Sohn criticized Pai's actions and noted that they "will make the market for Lifeline broadband services less competitive, limiting choice and keeping prices high. As a result, fewer low income Americans will be able to afford broadband."[160]

Chairman Pai released a clarifying statement in late March, noting "I want to make it clear that broadband will remain in the Lifeline program so long as I have the privilege of serving as Chairman… But as we implement the Lifeline program—as with any program we administer—we must follow the law. And the law here is clear: Congress gave state governments, not the FCC, the primary responsibility for approving which companies can participate in the Lifeline program under Section 214 of the Communications Act."[161]

[155] "Get Connected: Become a Lifeline Customer," Universal Service Administrative Company, http://www.lifelinesupport.org/ls/ (accessed March 2017).
[156] "Companies Near Me: California," Lifeline, Universal Service Administrative Company, http://www.lifelinesupport.org/ls/companies/CompanyListing.aspx?state=CA&stateName=California (accessed March 2017).
[157] "Lifeline Program for Low-Income Consumers," Federal Communications Commission, https://www.fcc.gov/general/lifeline-program-low-income-consumers (accessed March 2017).
[158] "Change My Company," Lifeline, Universal Service Administrative Company, http://www.lifelinesupport.org/ls/change-my-company.aspx (accessed March 2017).
[159] Brian Fung, "The FCC is stopping 9 companies from providing federally subsidized Internet to the poor," *Washington Post*, February 3, 2017, https://www.washingtonpost.com/news/the-switch/wp/2017/02/03/the-fcc-is-stopping-9-companies-from-providing-subsidized-broadband-to-the-poor/?utm_term=.2a7ab9593e96 (accessed March 2017).
[160] Gigi Sohn, "Defending the Indefensible: Chairman Pai's Lifeline Reversal Will Widen the Digital Divide," Blog Posting, Benton Foundation, https://www.benton.org/blog/Defending-the-Indefensible (accessed March 2017).
[161] "Statement of FCC Chairman Ajit Pai: On the Future of Broadband in the Lifeline Program," News Release, Federal Communications Commission, March 29, 2017, https://www.fcc.gov/document/chairman-pai-future-broadband-lifeline-program (accessed March 2017).

Low income residents can also obtain free devices that will connect to Wi-Fi networks provided by the City, community centers, and businesses through the federal Lifeline Assistance Program. Known colloquially as "Obamaphones," these devices are Wi-Fi enabled and provided at no cost to low-income Americans who qualify. There is much anecdotal evidence of the devices' use in low-income and homeless communities both in San Francisco and nationwide. While many Lifeline wireless carriers offer limited amounts of mobile data (50 to 500 MB per month),[162,163,164] there is no option to increase the amount of data on the plans. For homeless and low-income families, the device's internet functionality is dependent on the availability of Wi-Fi service in the City.

Costs for Items Other Than Broadband Services Also Impact Broadband Adoption Rates

It should be noted that monthly service costs are not the only prohibitive factor for non-broadband adopters. In the Pew Research poll, 10 percent of respondents cited the high cost of purchasing a computer as the reason they do not have broadband access. While investigating barriers to broadband adoption, Dailey et. al found "hardware and software costs, installation costs and deposits, equipment maintenance fees, transaction costs for disconnecting, and changes to subscription pricing all introduce additional—and often unpredictable—layers of cost."[165] For respondents to Dailey's surveys, these unanticipated costs "were often cited as reasons for dropping broadband at home."[166]

Factors Other Than Cost Also Impact Broadband Adoption Rates

A lack of digital and internet literacy and computer skills make the task of getting online feel daunting, and contribute to lower broadband adoption rates. Many Americans of all ages lack the technical skills needed to feel comfortable and confident accessing online resources and services, but the digital readiness gap is especially pronounced among older adults, who grew up in an era before the internet became integrated into everyday life. A 2016 Pew Research Center study found that 52 percent of adults were relatively hesitant to access online learning services.[167] A 2014 study also found that nearly one third of Americans had low levels of digital

[162] "Lifeline Program Description," Assurance Wireless, http://www.assurancewireless.com/Public/MorePrograms.aspx (accessed March 2017).
[163] "Plans," Life Wireless, https://www.lifewireless.com/main/plans (accessed March 2017).
[164] "Frequently Asked Lifeline Questions," enTouch Wireless, https://www.entouchwireless.com/pages/free_phone_more_info#collapse-TwentyFour (accessed March 2017).
[165] "Broadband Adoption in Low-Income Communities," Social Science Research Council, March 2010, http://webarchive.ssrc.org/broadband_adoption.pdf (accessed March 2017).
[166] Ibid.
[167] John Horrigan, "Digital Readiness Gaps," Pew Research Center, September 20, 2016, http://www.pewinternet.org/files/2016/09/PI_2016.09.20_Digital-Readiness-Gaps_FINAL.pdf (accessed March 2017).

skills, and this lack of skills have the largest impact on determining what online services an individual will access.[168]

Even some users who have the technical capabilities to use the internet to access certain services or resources still may not feel comfortable accessing other services due to a lack of trust or understanding of privacy issues. According to a 2015 NTIA survey, "84 percent of online households named at least one concern they had about online privacy and security risks," including identity theft, credit card fraud, data collection, loss of control over private data, data collection by government and threats to personal safety.[169] These fears lead some individuals to stay off line altogether, while others limit their internet use to activities they feel comfortable with.

Many individuals will not want internet enough to sign up for home broadband service until they gain the skills they need to feel confident and comfortable online. Many organizations have developed successful programs that help low-income and elderly populations develop the digital literacy skills they need to take advantage of online resources and services.[170] The most successful programs use relevant content, and establish trust between the individuals and the organizations offering the service.[171] These efforts help build demand for the internet, and, together with low-cost access to broadband and hardware, lead to higher rates of broadband adoption.

Digital Inclusion Can Be Expanded Through Low-Cost, High-Bandwidth Services

Making reliable, high-bandwidth, home broadband service available at an affordable price will not solve all digital inclusion problems, but it will make a substantial difference on the supply side of the challenge. Comcast's Internet Essentials program has made good progress in this direction, but it is not available to all low-income individuals, and with advertised speeds 'up to 10Mbps,' it will not support many of the data-hungry applications that are quickly being integrated into schools and workplaces.

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[168] John Horrigan, "Digital Readiness: Nearly one-third of Americans lack the skills to use next-generation 'Internet of things' applications," June 2014, http://jbhorrigan.weebly.com/uploads/3/0/8/0/30809311/digital_readiness.horrigan.june2014.pdf (accessed March 2017).

[169] Rafi Goldberg, "Lack of Trust in Internet Privacy and Security May Deter Economic and Other Online Activities," Blog Posting, National Telecommunications and Information Administration, May 13, 2016, https://www.ntia.doc.gov/blog/2016/lack-trust-internet-privacy-and-security-may-deter-economic-and-other-online-activities (accessed March 2017).

[170] "Strategies and Recommendations for Promoting Digital Inclusion," Consumer and Governmental Affairs Bureau, Federal Communications Commission, January 11, 2017, https://apps.fcc.gov/edocs_public/attachmatch/DOC-342993A1.pdf (accessed March 2017).

[171] "Libraries' Increasing Role in Broadband Adoption: Barriers: Digital Literacy, Relevancy & Cost," Benton Foundation, January 2016, https://www.benton.org/initiatives/libraries-broadband-adoption/barriers (accessed March 2017).

In order to move beyond the digital divide, low-income individuals and families need to have access to a similar online experience as their higher-income counterparts. If affordable home broadband services only provide a second-class experience, they will continue to hinder low-income individuals' ability to fully partake in economic, educational, and civic life in the 21st century. Instead of building demand for home broadband, a slow service could generate frustration and cause some users to give up on home broadband service altogether.

A better approach, in terms of meeting the City's policy goals, would be to make the same service that is available on the open market (i.e., the standard, off-the-shelf service that consumers can buy) available to low-income consumers at a reduced rate.

Creating a special, deliberately inferior product (i.e., lower speed) at a reduced rate for low-income consumers is the approach taken by Comcast for its Internet Essentials program and by AT&T for its Access service. These products are low cost only in terms of the monthly fee in comparison to other broadband services on the market; they are not low-fee on a per-megabit basis.

This means that the industry's low-cost digital inclusion services are very basic. They do not enable many of the applications that are fundamental to the internet today, such as streaming educational videos.

The alternative approach to creating a digital inclusion product is to make available an internet product that has the same level of quality that wealthy people are able to buy, but to make it available to low-income consumers at lower cost. This was the model initially adopted for the Lifeline program for voice communications.

Given everything discussed here—including the importance of bandwidth, and the fact that while many low-income residents already have access to Comcast and AT&T's products, those products are not equivalent to what wealthy people are able to buy (and are not transformative for low-income users)—the Fiber for San Francisco Initiative should consider prioritizing the second model, not the first.

That said, for individuals struggling to make ends meet, even a $10 a month service can be difficult to afford. Successful digital inclusion efforts often go a step further in trying to meet people where they are, providing as much flexibility in payment options as possible.

For example, PCs for People in St. Paul, Minnesota, sets up prepaid plans for their clients, and allows them to pay cash for one-month, three-month, six-month, or 12-month periods of service at a time. The organization offers the first three months free, to help offset the cost of the router and allow their clients to save up before another payment was due. If they do not have enough saved up by the time the next payment is due, their service is just put on hold until they make their next payment. And instead of having to interface with a large, corporate customer support system, users can walk in to a local facility staffed with friendly individuals that want to help them get online.[172]

In Wilson, North Carolina, a partnership between the municipal Greenlight network and the local housing authority allows residents to sign up for 50 Mbps symmetrical service at $10 per month. The housing authority provides residents with a free router, thus eliminating additional startup costs, and then adds the monthly fee to users' existing monthly bills, simplifying the payment process.[173]

To maximize the impact of an affordable, high-bandwidth service, it will need to be paired with digital literacy training, low-cost hardware initiatives, and public access computer centers that offer support. These complementary initiatives will help build demand for high-speed home broadband.

However, in many cases, the demand for home broadband is already there. There is simply no one offering to supply adequate service at a price that low-income individuals can afford.

[172] Angela Siefer, "Innovators in Digital Inclusion: PCs for People," Benton Foundation, September 28, 2016, https://www.benton.org/blog/innovators-digital-inclusion-pcs-people (accessed March 2017).
[173] Christopher Mitchell, "Wilson Greenlight, Public Housing Authority Solve Access Gap - Community Broadband Bits Episode 236," *Community Networks,* January 17, 2017, https://muninetworks.org/content/transcript-community-broadband-bits-episode-236 (accessed March 2017).

Appendix I: Potential Technical Framework for the Lit Fiber, Multi-Provider, Open-Access Network

The following describes, at a high-level, our recommendations for the Lit Fiber network that will be administered by the Lit Fiber Concessionaire: An open-access FTTP network capable of simultaneous use by multiple Retail Service Providers (RSP).

An open-access FTTP network serves as a platform for multiple service providers to reach subscribers over a shared infrastructure. The network model provides a centralized place where RSPs can connect to the network and deliver their services to their subscribers.

This shared last-mile fiber will reduce the cost for new service providers to enter the market, reduce redundant and costly builds to reach subscribers, and give subscribers more choices for service providers to meet their connectivity needs.

Network Architecture

This open-access network model takes a layered approach to dividing the responsibilities of running a fully-functional FTTP network. We describe the three roles as follows:

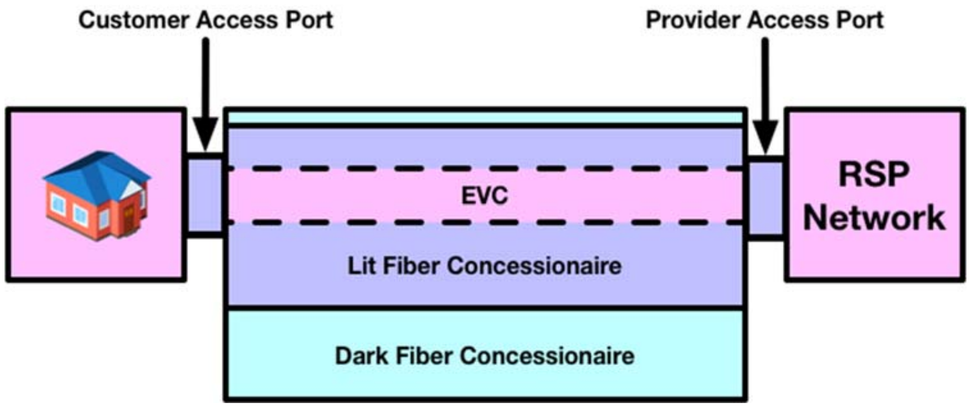
1. **Dark Fiber Concessionaire**: Responsible for the physical fiber plant. This includes construction, the initial network, responding to and repairing fiber breaks, constructing new fiber, splicing, and any ongoing maintenance tasks.

2. **Lit Fiber Concessionaire:** Responsible for lit services and the network electronics required to deliver those services. This includes provisioning services between RSPs and their subscribers and acting as a central point of contact for the network: providing service to RSPs and dispatching the Dark Fiber Concessionaire when fiber work is required. The Lit Fiber Concessionaire will also provide NOC services and operate a Civic Network and self-service portal.

3. **Retail Service Provider (RSP):** Responsible for providing network services, such as an internet connection, to subscribers over the FTTP network. RSPs obtain access to the FTTP network through the Lit Fiber Concessionaire and sell their services to subscribers on the network.

Figure 22 illustrates the responsibilities of a Dark Fiber Concessionaire, a Lit Fiber Concessionaire, and a Retail Service Provider in a layered service model.

Figure 22: Responsibilities in a Layered Service Model



The primary goal of the FTTP network is to provide a fast, secure, and reliable connection between an RSP and its subscribers. The FTTP network will allow an RSP to connect via a "provider access port" and offer retail service to any subscriber on the network.

The Lit Fiber Concessionaire will create an EVC (Ethernet virtual connection) that associates an RSP access port with one or more subscriber connections, in effect, creating a "pipe" between an RSP and their subscribers. Many EVCs can be created to carry various services from different RSPs across the network in a secure way.

The Lit Fiber Concessionaire may employ various networking technologies and create a network that is as complex or as simple as necessary and still present the EVC as a simple connection between an RSP and its subscribers.

Figure 23 illustrates how multiple RSPs can connect to the FTTP network and provide various services to connected subscribers.

Figure 23: Multiple Services Provided over the Same FTTP Network

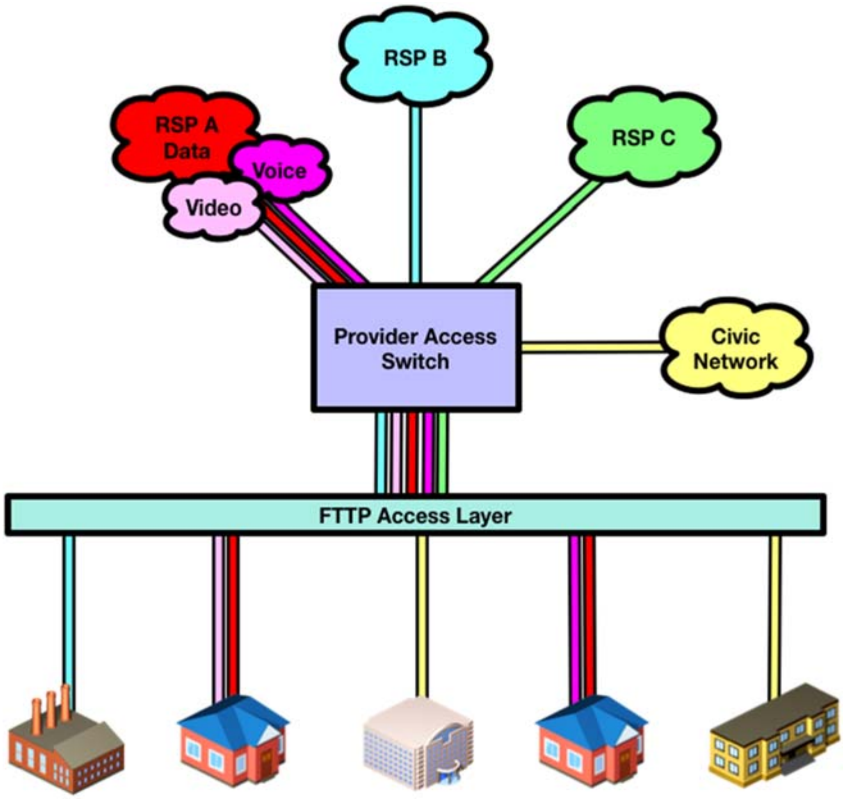
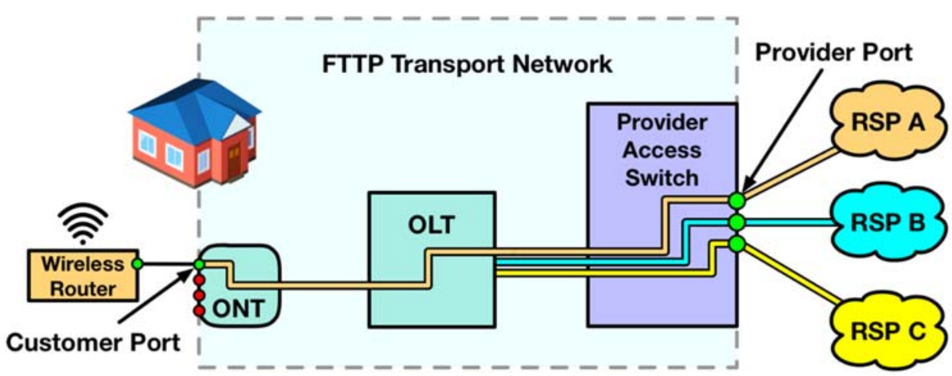


Figure 24 illustrates an EVC provisioned between RSP A's port and a port on a subscriber's ONT. All three service providers shown have their own EVC on the network, but only RSP A's service is provisioned to this particular customer.

Figure 24: Service from RSP A Is Provisioned to the Customer ONT via an EVC



The FTTP network should allow for multiple types of EVC services including:

1. Point-to-point services used to connect two subscriber locations (Figure 25)
2. Multipoint (LAN) services used to interconnect more than two locations (Figure 26)
3. "Tee" services used to connect multiple "leaf" locations back to a "root" location which allows the leaf locations to communicate with the root, but not with one another (Figure 27)

A tree service may be desirable for certain applications such as residential internet service or a corporate WAN where branch locations should not be able to see each other's traffic.

The network also must allow for performance monitoring or individual EVCs and quality of service classifications so that SLAs can be monitored and enforced or so that certain traffic, such as live video or VoIP traffic, can be prioritized when crossing the FTTP network.

Figure 25: A Point-to-Point Topology

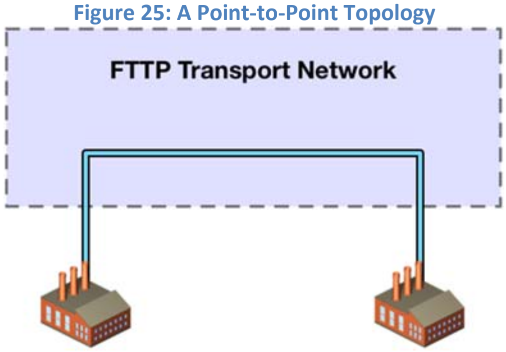


Figure 26: A Multipoint, or LAN, Topology

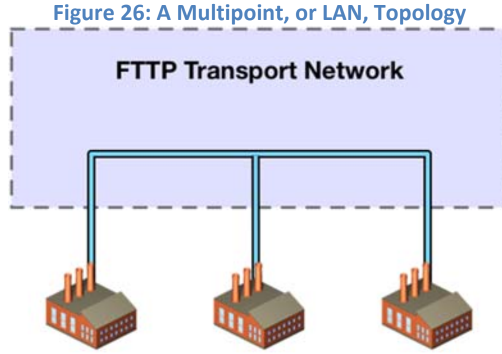
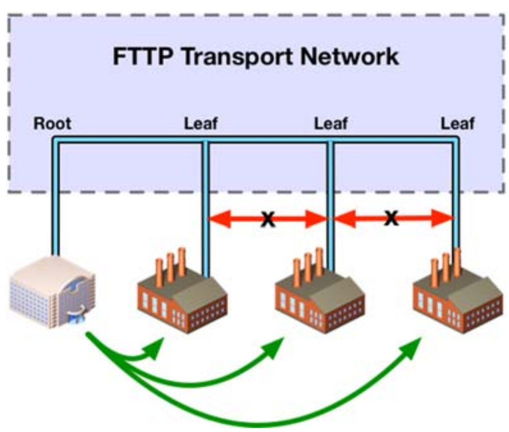


Figure 27: A Tree Topology

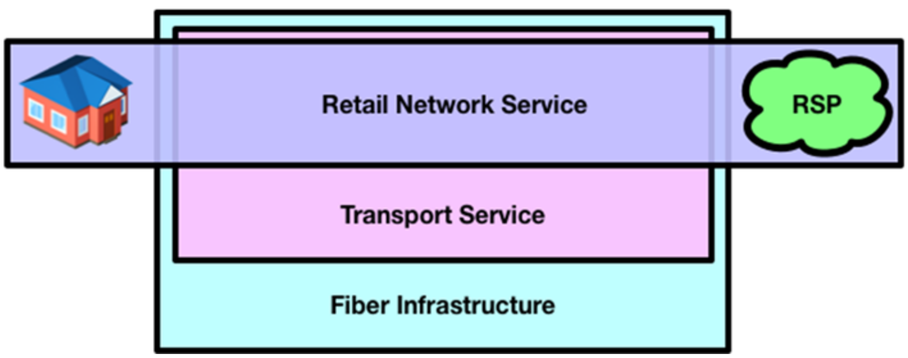


Network Operational Model

We divide the operational responsibilities for the FTTP network into three layered categories: fiber maintenance, transport service, and retail service (Figure 28). The Dark Fiber Concessionaire will be responsible for constructing and maintaining the physical fiber plant, the Lit Fiber Concessionaire will be responsible for operating transport service over the physical fiber plant, and multiple RSPs will connect to the network and purchase transport services in order to provide retail network services to subscribers. This model establishes clear separation of responsibilities and lines of communication.

- **Fiber maintenance:** Responsibility for the physical fiber plant. This includes responding to and repairing fiber breaks, constructing new fiber as required, splicing, and any ongoing maintenance tasks.
- **Transport service:** Responsibility for lit services and network electronics (routers and switches) and at the fiber access layer (OLT and ONT). This includes provisioning services between subscribers and services providers and providing network monitoring services.
- **Retail network service:** Responsibility for providing network services, such as an internet connection, to subscribers over the FTTP network.

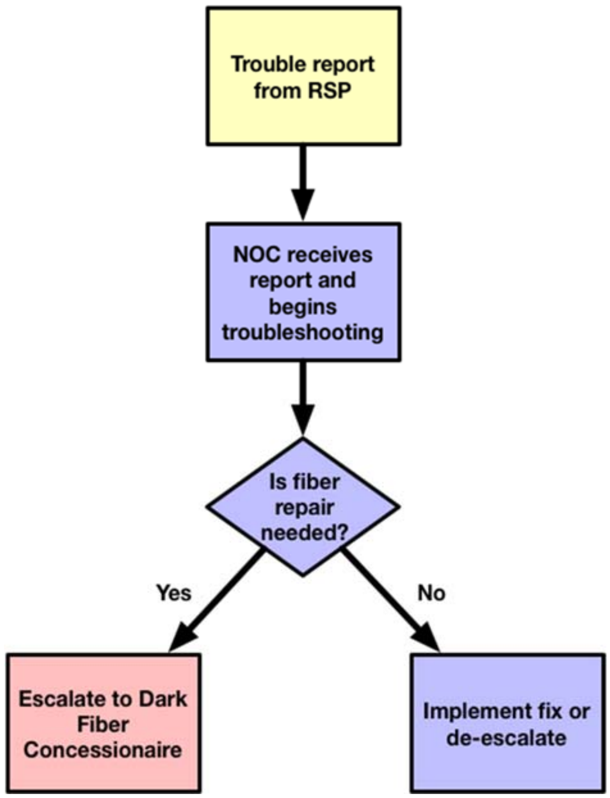
Figure 28: Layered Operational Responsibilities for the Open-Access FTTP Network



The Lit Fiber Concessionaire serves a central role in this operational model. They are responsible not only for operating transport services, but also for providing NOC (network operations center) services which include monitoring, troubleshooting, and fixing the transport network; providing support and provisioning services for RSPs; and engaging the Dark Fiber Concessionaire when a fix or new fiber installation is required. The NOC should serve as a single point of contact for RSPs and the Dark Fiber Concessionaire while the subscriber relationship should be managed by the RSPs.

The NOC should actively monitor the network and its services and proactively find and resolve issues on the network. The Lit Fiber Concessionaire should also provide the RSPs with some view into their monitoring solution. RSPs should also be able to escalate trouble reports to the Lit Fiber Concessionaire (Figure 29). The Lit Fiber Concessionaire will assist in troubleshooting and determine whether the issue is with the transport network, the physical fiber plant, or an issue with the RSP or subscriber network and direct the issue to the correct group.

Figure 29: Trouble Report Workflow



New Subscriber Provisioning

The Lit Fiber Concessionaire will be responsible for accepting requests from RSPs for new services to be provisioned. Most service requests will fall into one of three categories:

- An RSP wishes to offer service in a new area. This will require installation of a new fiber distribution cabinet (FDC) and new fiber to connect the FDC to the network and to the subscriber premises within the new service area.
- An RSP wishes to offer service to a new subscriber premises in an existing service area. This will require either installation of a service drop between the subscriber premises and existing FDC or constructing a lateral fiber connection from an existing fiber cable as well as configuration and installation of new electronics and provisioning service to the new subscriber.
- An RSP wishes to offer new service or change existing services at an existing subscriber premises. This will require provisioning an RSP's EVC to an existing subscriber port.

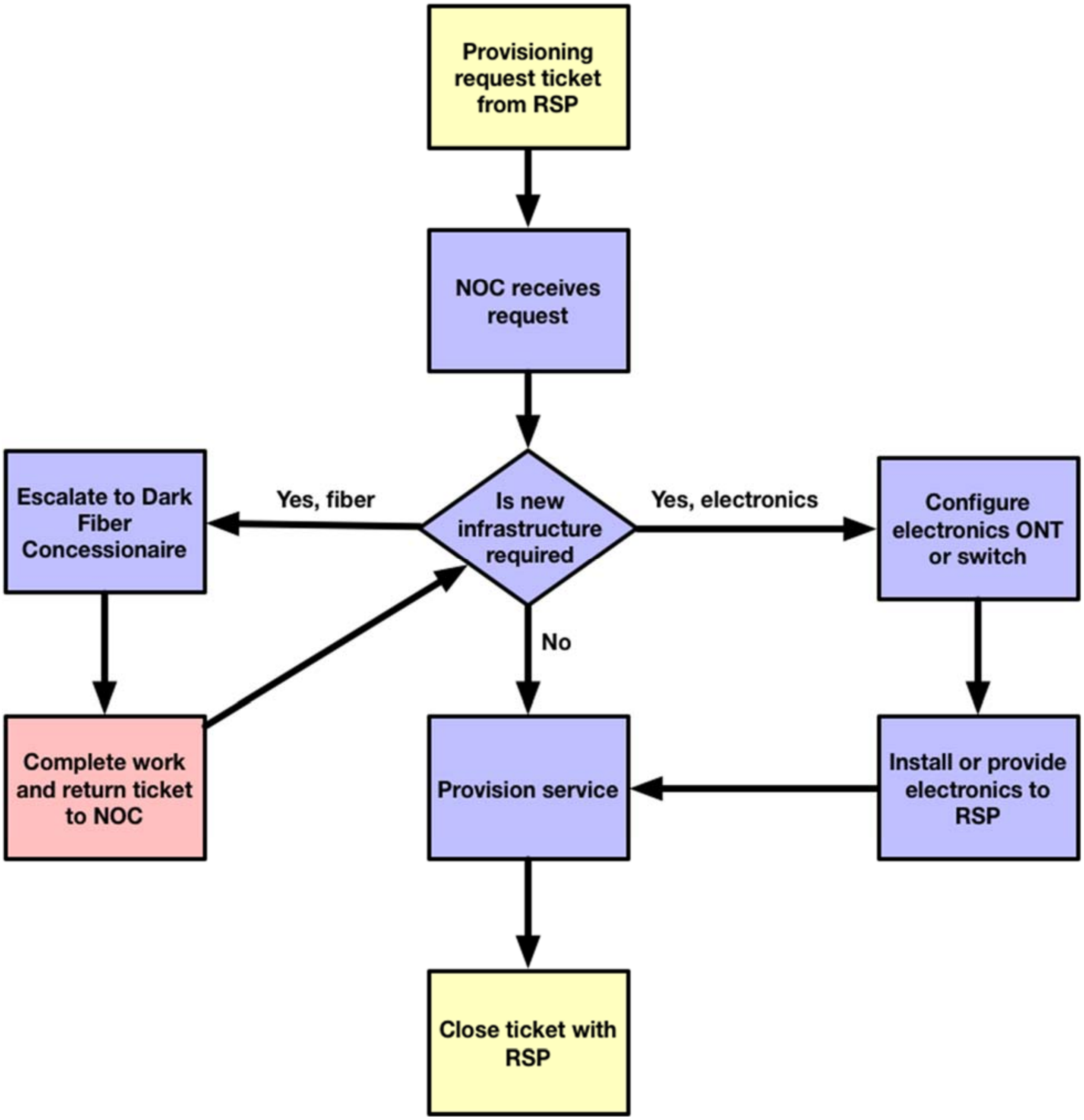
Services requiring new fiber: If a service requires new fiber, the Lit Fiber Concessionaire will engage the services of the Dark Fiber Concessionaire and provide an estimated completion date. Depending on the model being used, the Dark Fiber Concessionaire may install and configure an ONT or switch at the subscriber premises as part of the construction process.

Services requiring new electronics: We envision a scenario where the Lit Fiber Concessionaire will pre-configure and pre-provision a new subscriber ONT and provide it to the RSP to be installed along with the service provider's CPE. This process would limit the number of visits required to the subscriber premises and allow the retail service provider to have more control over the subscriber relationship. The Lit Fiber Concessionaire would need to be immediately available to provide assistance if the retail service provider is unable to bring up the subscriber connection.

Alternatively, the ONT may be installed by the Dark Fiber Concessionaire during the fiber construction process. This would allow the transport service to be fully-tested before the retail service provider arrives and may be more desirable in certain scenarios, such as cases where the ONT is being installed on the outside of the subscriber building, where the fiber installation process necessitates entry into the subscriber premise, or where configuration and provisioning of the ONT requires that the ONT be installed and active.

Services requiring provisioning to an existing subscriber port: The Lit Fiber Concessionaire will implement a self-service portal that allows subscribers to select standard services from available retail providers. (This self-service portal is described in greater detail in Section 7.4.5.) For more advanced services, the Lit Fiber Concessionaire NOC should be prepared to provision the appropriate subscriber ports within a time frame that will be specified in the provider's SLA (Figure 30).

Figure 30: Service Provisioning Workflow



Appendix J: Financial Analysis of Purely Public Model

To fully understand the potential viability of the purely public model for this initiative, the Project Team developed a full financial model and analysis of the economics of the traditional municipal ownership and operations model.

Framework

The financial analysis in this section assumes the City owns, operates, and provides retail voice, video, and data services to residents and businesses in the community. The analysis is based on the low-cost model developed by the engineers[174] and the assumptions described below.

The model is designed to be cash flow positive in year one; this is accomplished through bond and loan financing. Over time, given the lower cost estimate to construct, maintain, and operate the FTTP network, the model indicates that a 47 percent take rate of households and businesses passed will be required to break even.

The analysis assumes that the City offers three data services:

- 1 Gbps residential service at $80 per month
- 1 Gbps small commercial service at $90 per month
- 1 Gbps medium commercial service (with service-level agreements) at $240 per month[175]

These service prices are above those of Google Fiber in other markets ($70 for 1 Gbps) but are lower than some other providers' pricing. For example, Comcast's recently announced residential 1 Gbps service is likely to be priced in excess of $150 per month.

The analysis assumes that 25 percent of business customers will purchase the higher-level service. It also assumes that the City will offer video and data services through a service partner or contractor. For video, we assume that customers will pay an average package price of $85 per month, and that the City will receive $12.75. For telephone, we assume that two services are offered—a residential service at $20 per month and a business line at $40 per month—and that the City will receive $5 per month and $10 per month, respectively.

Table 33 represents a summary of this model.

[174] The implications of the higher cost estimate are described as a scenario below.
[175] Medium commercial service receives a lower oversubscription rate, that is, less customers sharing the connection, decreasing the instances of network congestion reducing overall speeds.

Table 33: Municipal Retail Model Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$16,056,195	$226,825,740	$222,822,540	$222,822,540	$222,822,540
Total Cash Expenses	(14,641,640)	(95,009,580)	(91,973,400)	(91,973,400)	(91,973,400)
Depreciation	(19,524,010)	(83,441,050)	(78,874,790)	(77,234,410)	(77,234,410)
Interest Expense	(16,457,000)	(57,012,630)	(44,572,300)	(28,991,300)	(9,308,020)
Taxes	-	-	-	-	-
Net Income	$(34,566,455)	$(8,637,520)	$7,402,050	$24,623,430	$44,306,710

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$498,455	$9,553,265	$22,393,535	$38,247,385	$54,219,245
Depreciation Reserve	-	61,421,730	71,081,400	10,923,510	16,297,160
Interest Reserve	15,057,000	-	-	-	-
Debt Service Reserve	16,730,000	64,420,000	64,420,000	64,420,000	64,420,000
Total Cash Balance	$32,285,455	$135,394,995	$157,894,935	$113,590,895	$134,936,405

The model assumes that subscribership for data services will ramp up over years one through four, and then remain steady. The model assumes that subscribership for voice and video services will ramp up over the same period, but then decline as adoption of over-the-top (OTT) alternatives increases.[176]

Financing Costs

This financial analysis assumes that the City will seek a series of bonds and a one-time loan. It assumes that a debt service reserve of 5 percent and an interest reserve account is required for the bonds.

The analysis estimates total financing requirements to be almost $1.29 billion in bonds and a $20 million loan. The bonds are issued at a 4.5 percent finance rate and principal payments start in the third year after issuance.

We also assume a 20-year, $20 million loan is obtained in in year one. The loan is issued at a 7 percent finance rate and principal payments start in sixth year after issuance.

The model assumes a straight-line depreciation of assets, and that the outside plant will have a 20-year life span while the network equipment will need to be replaced after 10 years. Customer Premises Equipment (CPE) as well as other miscellaneous equipment (test equipment, vehicles,

[176] The analysis uses a flat model (i.e., does not include inflation and salary cost increases because those operating cost increases will be offset and passed on to subscribers in the form of increased prices). Models that add an inflation factor to both revenues and expenses typically greatly overstate future cash flow because net revenues are unlikely to increase as quickly as inflation. At best, the provider will be able to match expenses increases with a dollar-for-dollar rate increase, which is what the flat model represents.

computers) will need to be replaced every five years. Network equipment, including last mile and CPEs will be replaced or upgraded at 80 percent of original cost, miscellaneous implementation costs at 100 percent. The model plans for a depreciation reserve account, starting in year three, to fund future electronics replacements and upgrades.

Table 34 shows the income statement for years one, five, 10, 15, and 20. The City's net income is about negative $34.6 million in year one, and negative $8.6 million in year five. By year 10, the operation will generate a net income just under $7.4 million, growing to just over $24.6 million in year 15, and just over $44.3 million in year 20.

Table 35 shows the cash flow statement for years one, five, 10, 15, and 20. The unrestricted cash balance is approximately $498,000 in year one and $22.4 million in year 10. By year 15, the unrestricted cash balance is just over $38.2 million; it is just over $54.2 million by year 20.

Table 34: Income Statement

Income Statement		Year 1	Year 5	Year 10	Year 15	Year 20
Revenues						
Video		$5,595,720	$39,615,780	$39,615,780	$39,615,780	$39,615,780
Internet - Residential		8,004,480	160,089,600	160,089,600	160,089,600	160,089,600
Internet - Business		672,120	13,428,360	13,428,360	13,428,360	13,428,360
Enterprise		-	-	-	-	-
Voice		1,125,600	13,692,000	9,688,800	9,688,800	9,688,800
Connection Fee (net)		658,275	-	-	-	-
Ancillary Revenues		-	-	-	-	-
	Total	$16,056,195	$226,825,740	$222,822,540	$222,822,540	$222,822,540
Content Fees						
Video		$4,759,830	$33,674,280	$33,674,280	$33,674,280	$33,674,280
Internet		124,350	2,418,490	2,418,490	2,418,490	2,418,490
Enterprise		-	-	-	-	-
Voice		844,200	10,269,000	7,266,600	7,266,600	7,266,600
	Total	$5,728,380	$46,361,770	$43,359,370	$43,359,370	$43,359,370
Operating Costs						
Operation Costs		$4,923,260	$28,186,810	$28,153,030	$28,153,030	$28,153,030
Labor Costs		3,990,000	20,461,000	20,461,000	20,461,000	20,461,000
	Total	$8,913,260	$48,647,810	$48,614,030	$48,614,030	$48,614,030
EBITDA		$1,414,555	$131,816,160	$130,849,140	$130,849,140	$130,849,140
Depreciation		19,524,010	83,441,050	78,874,790	77,234,410	77,234,410
Operating Income (EBITDA less Depreciation)		$(18,109,455)	$48,375,110	$51,974,350	$53,614,730	$53,614,730
Non-Operating Income						
Interest Income		$-	$314,600	$338,750	$188,360	$201,790
Interest Expense (10 Year Bond)		-	-	-	-	-
Interest Expense (20 Year Bond)		(15,057,000)	(55,927,230)	(43,758,410)	(28,446,980)	(9,366,150)
Interest Expense (Loan)		(1,400,000)	(1,400,000)	(1,152,640)	(732,680)	(143,660)
	Total	$(16,457,000)	$(57,012,630)	$(44,572,300)	$(28,991,300)	$(9,308,020)
Net Income (before taxes)		$(34,566,455)	$(8,637,520)	$7,402,050	$24,623,430	$44,306,710
Facility Taxes		$ -	$ -	$ -	$ -	$ -
Net Income		$(34,566,455)	$(8,637,520)	$7,402,050	$24,623,430	$44,306,710

Table 35: Cash Flow Statement

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
a. Net Income	$(34,566,455)	$(8,637,520)	$7,402,050	$24,623,430	$44,306,710
b. Cash Outflows					
Debt Service Reserve	$(16,700,000)	$ -	$ -	$ -	$ -
Interest Reserve	(30,114,000)	-	-	-	-
Depreciation Reserve	-	(21,277,470)	(20,113,070)	(19,694,770)	(19,694,770)
Financing	(3,346,000)	-	-	-	-
Capital Expenditures	(303,926,100)	-	-	-	-
Total	$(354,116,100)	$(21,277,470)	$(20,113,070)	$(19,694,770)	$(19,694,770)
c. Cash Inflows					
Interest Reserve	$15,057,000	$3,307,500	$ -	$ -	$ -
Depreciation Reserve	-	-	-	-	-
Investment Capital	-	-	-	-	-
10-Year Bond/Loan Proceeds	-	-	-	-	-
20-Year Bond Proceeds	334,600,000	-	-	-	-
Loan Proceeds	20,000,000	-	-	-	-
Total	$369,657,000	$3,307,500	$ -	$ -	$ -
d. Total Cash Outflows and Inflows	$15,540,900	$(17,969,970)	$(20,113,070)	$(19,694,770)	$(19,694,770)
e. Non-Cash Expenses – Depreciation	$19,524,010	$83,441,050	$78,874,790	$77,234,410	$77,234,410
f. Adjustments					
Proceeds from Additional Cash Flows (10 Year Bond)	$-	$-	$-	$-	$-
Proceeds from Additional Cash Flows (20 Year Bond)	$(334,600,000)	$-	$-	$-	$-
Proceeds from Additional Cash Flows (Loan)	$(20,000,000)	$-	$-	$-	$-
g. Adjusted Available Net Revenue	$(354,101,545)	$56,833,560	$66,163,770	$82,163,070	$101,846,350
h. Principal Payments on Debt					
10 Year Bond Principal	$-	$-	$-	$-	$-
20 Year Bond Principal	-	47,289,880	62,195,610	77,507,040	96,587,870
Loan Principal	-	-	1,043,250	1,463,220	2,052,240
Total	$-	$47,289,880	$63,238,860	$78,970,260	$98,640,110
i. Net Cash	$498,455	$9,543,680	$2,924,910	$3,192,810	$3,206,240
j. Cash Balance					
Unrestricted Cash Balance	$498,455	$9,553,265	$22,393,535	$38,247,385	$54,219,245
Depreciation Reserve	-	61,421,730	71,081,400	10,923,510	16,297,160
Interest Reserve	15,057,000	-	-	-	-
Debt Service Reserve	16,730,000	64,420,000	64,420,000	64,420,000	64,420,000
Total Cash Balance	$32,285,455	$135,394,995	$157,894,935	$113,590,895	$134,936,405

Capital Additions

Significant network expenses, known as capital additions, are incurred in the first few years during the construction phase of the network. These represent the equipment, material and construction labor associated with building, implementing, and lighting a fiber network. Table 36 shows the capital additions costs in years one through four, assuming a 48 percent take rate, or about 175,500 customers.

This analysis projects that capital additions in year one will total approximately $303.9 million. These costs will total approximately $486.3 million in year two, just under $342.6 million in year three, and $106.2 million in year four.

Table 36: Capital Additions

Capital Additions	Year 1	Year 2	Year 3	Year 4
Network Equipment				
Core & GPON Equipment	$65,615,200	$16,403,800	$ -	$ -
Additional Annual Capital	-	-	-	-
Total	$65,615,200	$16,403,800	$ -	$ -
Outside Plant and Facilities				
Total Backbone and FTTP	$214,675,200	$357,792,000	$143,116,800	$ -
Additional Annual Capital	-	-	-	-
Total	$214,675,200	$357,792,000	$143,116,800	$ -
Last Mile and Customer Premises Equipment				
CPE (residential and small commercial)	$5,762,600	$28,654,300	$51,033,800	$27,170,000
CPE (medium commercial)	77,000	384,300	690,900	383,600
CPE (enterprise)	-	-	-	-
Average Drop Cost	16,656,100	82,810,000	147,476,700	78,530,100
Additional Annual Replacement Capital	-	-	-	-
Total	$22,495,700	$111,848,600	$199,201,400	$106,083,700
Miscellaneous Implementation Costs				
OSS	$400,000	$ -	$ -	$ -
Vehicles	70,000	140,000	105,000	-
Emergency Restoration Kit	100,000	-	-	-
Work Station, Computers, and Software	70,000	138,000	170,000	82,000
Fiber OTDR and Other Tools	100,000	-	-	-
Billing Software	250,000	-	-	-
Fiber Management Software	150,000	-	-	-
Additional Annual Capital	-	-	-	-
Total	$1,140,000	$278,000	$275,000	$82,000
Total Capital Additions	$303,926,100	$486,322,400	$342,593,200	$106,165,700

Operating and Maintenance Expenses

Under the assumptions in the model, the City's operating and maintenance expenses, including principal and interest payments, will total over $31 million in year one, growing to $199.3 million in year five, $199.7 million in year 10, and $199.9 million in years 15 and 20.

O&M expenses include staffing for sales and marketing, network operations, and other functions new to the City. The addition of new staff will require new office space. Similarly, network inventory requirements will require warehousing space. The model builds in costs for the City to:

- Expand office facilities for management, technical, and clerical staff
- Open a retail storefront to facilitate customer contact and enhance their experience doing business with the FTTP enterprise
- Provide warehousing for receipt and storage of cable and hardware for the installation and ongoing maintenance of the broadband infrastructure
- Establish a location to house servers, switches, routers, and other core network equipment

Training new and existing staff will be required to fully realize the economies of starting the FTTP network. Marketing and sales will also be required, and will represent a new activity for the City.

Staffing with skills in the following disciplines will be required:

- Sales/Promotion
- Internet and related technologies
- Staff Management
- Strategic Planning
- Finance
- Vendor Negotiations
- Networking (addressing, segmentation)
- Marketing

The expanded business and increased responsibilities will require the addition of new staff. The initial additional positions, staffing levels, and base salaries are shown in Table 37. These numbers assume two shifts of customer service representative support and 1.5 shifts of customer technicians. Changing to full 24x7 staffing will increase costs. Similarly, reducing the support hours (e.g., to 7 a.m. to 8 p.m.) will decrease the required staffing.

Note that Table 37 lists only new employees—the model assumes no existing staff will be allocated to the enterprise. The listed salaries do not include overhead. To account for overhead, the model adds 40 percent to the base salaries.

Table 37: Labor Expenses

New Employees	Year 1	Year 2	Year 3	Year 4	Year 5+	Year 1 Salary
Business Manager	1.00	1.00	1.00	1.00	1.00	$150,000
Marketing & Sales Manager	1.00	1.00	1.00	1.00	1.00	$125,000
GIS & Recordkeeping	2.00	3.00	3.00	3.00	3.00	$90,000
Network Engineer	2.00	3.00	3.00	3.00	3.00	$120,000
Network Technicians	4.00	6.00	6.00	6.00	6.00	$80,000
Sales & Marketing Representatives	10.00	20.00	25.00	25.00	25.00	$65,000
Customer Service Representatives	4.00	24.00	56.00	74.00	74.00	$65,000
Service Technicians/Installers & IT Support	4.00	23.00	55.00	73.00	73.00	$90,000
HR, Administration & Support	1.00	3.00	3.00	3.00	3.00	$75,000
Call Center Support	2.00	8.00	18.00	23.00	23.00	$65,000
Fiber Plant O&M Technicians	4.00	12.00	18.00	18.00	18.00	$90,000
Total	35.00	104.00	189.00	230.00	230.00	

Additional key operating and maintenance assumptions include:

- Direct internet access costs are estimated at $0.50 per Mbps per month for the first 3,000 Mbps, and $0.40 per Mbps per month beyond that
- Insurance is estimated to be zero in year one and $400,000 from year two on
- Utilities are estimated to be $100,000 in year one and $200,000 from year two on
- Office expenses are estimated to be $200,000 in year one and $400,000 from year two on
- Facility lease fees are expected to be $240,000 in year one and $480,000 from year two on
- Locates and ticket processing are estimated to start in year one at $71,300, increase to $356,400 in year two, and increase to $712,900 from year three on
- Peering expenses are estimated at $42,100 in year one, $252,800 in year two, $631,900 in year three, and $842,600 in year four on
- Contingency is estimated to be $200,000 in year one and $400,000 from year two on
- Billing and maintenance contract fees are estimated at $75,000 from year two on
- Legal fees are estimated to be $200,000 in years one and two, and $100,000 from year three on
- Consulting fees are estimated at $150,000 in year one and $75,000 from year two on

- Marketing and promotional expenses are estimated to be $1 million in year one and $750,000 from year two on

Vendor maintenance contract fees are expected to start at $8.2 million in year two and remain steady from year two on (based upon 10 percent of accrued investment). Annual variable operating expenses not including direct internet access include:

- Education and training are calculated as 2 percent of direct payroll expense
- Allowance for bad debts is computed as 0.5 percent of revenues
- Churn is anticipated to be 6 percent annually, which initiates a $175 per subscriber acquisition cost.

The estimated cost of electronic billing for the new FTTP enterprise is $0.50 per bill. This is in addition to the $250,000 cost for the billing software, which will require updating every five years,[177] and $75,000 in annual software support fees.

Fiber network maintenance costs are calculated at 1 percent of the total construction cost, per year. This is estimated based on a typical rate of occurrence in an urban environment, and the cost of individual repairs. These costs will total $2.3 million in year one, $6.7 million in year two, $9.6 million in year three, and roughly $10.4 million in year four on. This is in addition to staffing costs to maintain the fiber.

Table 38 shows operating expenses for years one, five, 10, 15, and 20. As seen, some expenses will remain constant while others will increase as the network expands and the customer base increases.

[177] Replacement value estimated at 80 percent of the original cost.

Table 38: Operating Expenses and P&I Payments

Operating Expenses	Year 1	Year 5	Year 10	Year 15	Year 20
Support Services	$ -	$ -	$ -	$ -	$ -
Insurance	-	400,000	400,000	400,000	400,000
Utilities	100,000	200,000	200,000	200,000	200,000
Office Expenses	200,000	400,000	400,000	400,000	400,000
Facility Lease	240,000	480,000	480,000	480,000	480,000
Locates & Ticket Processing	71,300	712,900	712,900	712,900	712,900
Peering	42,100	842,600	842,600	842,600	842,600
Contingency	200,000	400,000	400,000	400,000	400,000
Billing Maintenance Contract	-	75,000	75,000	75,000	75,000
Fiber & Network Maintenance	2,313,310	10,410,570	10,410,570	10,410,570	10,410,570
Vendor Maintenance Contracts	-	8,201,800	8,201,800	8,201,800	8,201,800
Legal	200,000	100,000	100,000	100,000	100,000
Planning	-	-	-	-	-
Consulting	150,000	75,000	75,000	75,000	75,000
Marketing	1,000,000	750,000	750,000	750,000	750,000
Education and Training	79,800	409,220	409,220	409,220	409,220
Customer Handholding	-	-	-	-	-
Customer Billing (Unit)	55,640	1,080,940	1,075,940	1,075,940	1,075,940
Allowance for Bad Debts	80,280	1,134,130	1,114,110	1,114,110	1,114,110
Churn (acquisition costs)	97,380	1,891,650	1,882,890	1,882,890	1,882,890
Pole Attachment Expense	93,450	623,000	623,000	623,000	623,000
Video	4,759,830	33,674,280	33,674,280	33,674,280	33,674,280
Internet	124,350	2,418,490	2,418,490	2,418,490	2,418,490
Enterprise	-	-	-	-	-
Voice	844,200	10,269,000	7,266,600	7,266,600	7,266,600
Sub-Total	$10,651,640	$74,548,580	$71,512,400	$71,512,400	$71,512,400
Labor Expenses	$3,990,000	$20,461,000	$20,461,000	$20,461,000	$20,461,000
Sub-Total	$3,990,000	$20,461,000	$20,461,000	$20,461,000	$20,461,000
Total Expenses	$14,641,640	$95,009,580	$91,973,400	$91,973,400	$91,973,400
Principal and Interest	$16,457,000	$104,302,510	$107,811,160	$107,961,560	$107,948,130
Facility Taxes	-	-	-	-	-
Sub-Total	$16,457,000	$104,302,510	$107,811,160	$107,961,560	$107,948,130
Total Expenses, P&I, and Taxes	$31,098,640	$199,312,090	$199,784,560	$199,934,960	$199,921,530

Sensitivity Scenarios

To understand the sensitivity of the financial model to a range of possible outcomes, we developed sensitivity scenarios. Many of these scenarios may not be realistically attainable, but are meant to demonstrate the sensitivity of the financial projections to these assumptions.

Base Case

As we previously noted, the base case shows that a 47 percent take rate is required to break even, assuming the lower-cost construction estimate.[178] Table 39 shows a financial summary for this scenario.

Table 39: Base Case Scenario

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$16,056,195	$226,825,740	$222,822,540	$222,822,540	$222,822,540
Total Cash Expenses	(14,641,640)	(95,009,580)	(91,973,400)	(91,973,400)	(91,973,400)
Depreciation	(19,524,010)	(83,441,050)	(78,874,790)	(77,234,410)	(77,234,410)
Interest Expense	(16,457,000)	(57,012,630)	(44,572,300)	(28,991,300)	(9,308,020)
Taxes	-	-	-	-	-
Net Income	$(34,566,455)	$(8,637,520)	$7,402,050	$24,623,430	$44,306,710

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$498,455	$9,553,265	$22,393,535	$38,247,385	$54,219,245
Depreciation Reserve	-	61,421,730	71,081,400	10,923,510	16,297,160
Interest Reserve	15,057,000	-	-	-	-
Debt Service Reserve	16,730,000	64,420,000	64,420,000	64,420,000	64,420,000
Total Cash Balance	$32,285,455	$135,394,995	$157,894,935	$113,590,895	$134,936,405

Take Rate Drops by 10 Percentage Points

If the take rate were to drop by 10 percentage points, the enterprise would quickly turn from an unrestricted cash balance of about $406,000 in year one to a negative cash balance. By year five, the unrestricted cash balance deficit would be over $61.9 million, growing to a deficit of over $324 million by year 20.

[178] Indicates take rate in year 4. The take rate declines slightly over time due to the reduction of video and voice subscribers.

Table 40: Take Rate Drops by 10 Percent

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$12,644,430	$178,564,620	$175,415,820	$175,415,820	$175,415,820
Total Cash Expenses	(13,108,080)	(79,018,980)	(76,630,810)	(76,630,810)	(76,630,810)
Depreciation	(17,910,490)	(73,623,070)	(70,028,340)	(68,684,740)	(68,684,740)
Interest Expense	(15,669,500)	(52,030,410)	(40,592,890)	(26,281,980)	(8,223,660)
Taxes	-	-	-	-	-
Net Income	$(34,043,640)	$(26,107,840)	$(11,836,220)	$3,818,290	$21,876,610

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$406,050	$(61,936,285)	$(151,077,335)	$(237,684,675)	$(324,075,705)
Depreciation Reserve	-	54,423,780	71,837,970	32,135,980	46,109,470
Interest Reserve	14,269,500	-	-	-	-
Debt Service Reserve	15,855,000	58,730,000	58,730,000	58,730,000	58,730,000
Total Cash Balance	$30,530,550	$51,217,495	$(20,509,365)	$(146,818,695)	$(219,236,235)

Voice and Video Revenue Drops by 50 Percent

While the base case assumes that voice and video revenue will drop over time as customers turn to over-the-top (OTT) alternatives, we also assumed a revenue share with a voice and video provider. As the table below illustrates, reducing voice and video revenue by 50 percent from the base case turns the unrestricted cash balance negative by year 5, with the deficit increasing to just under $7 million by year 10. This deficit would be reduced over time, totaling $4.9 million by year 20.

Table 41: Voice and Video Revenue Share Drops by 50 Percent

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$16,056,195	$226,825,740	$222,822,540	$222,822,540	$222,822,540
Total Cash Expenses	(15,061,954)	(97,983,170)	(94,946,990)	(94,946,990)	(94,946,990)
Depreciation	(19,524,010)	(83,441,050)	(78,874,790)	(77,234,410)	(77,234,410)
Interest Expense	(16,457,000)	(57,012,630)	(44,572,300)	(28,991,300)	(9,308,020)
Taxes	-	-	-	-	-
Net Income	$(34,986,769)	$(11,611,110)	$4,428,460	$21,649,840	$41,333,120

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$78,141	$(4,964,808)	$(6,992,490)	$(6,006,592)	$(4,902,684)
Depreciation Reserve	-	61,421,730	71,081,400	10,923,510	16,297,160
Interest Reserve	15,057,000	-	-	-	-
Debt Service Reserve	16,730,000	64,420,000	64,420,000	64,420,000	64,420,000
Total Cash Balance	$31,865,141	$120,876,922	$128,508,910	$69,336,918	$75,814,476

Residential Internet Fee Decreases or Increases by $5 per Month

If competitive pressures force the City to reduce the residential internet service fee by $5 per month from the levels assumed in the base case, the enterprise would not be financially feasible.

By year 10, the unrestricted cash balance deficit would be more than $58.2 million, growing to a deficit of just under $126 million by the end of year 20 (see the table below).

Table 42: Residential Internet Fee Decreases by $5 per Month

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$15,555,915	$216,820,140	$212,816,940	$212,816,940	$212,816,940
Total Cash Expenses	(14,639,140)	(94,959,550)	(91,923,370)	(91,923,370)	(91,923,370)
Depreciation	(19,524,010)	(83,441,050)	(78,874,790)	(77,234,410)	(77,234,410)
Interest Expense	(16,457,000)	(57,012,630)	(44,572,300)	(28,991,300)	(9,308,020)
Taxes	-	-	-	-	-
Net Income	$(35,064,235)	$(18,593,090)	$(2,553,520)	$14,667,860	$34,351,140

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$675	$(21,309,005)	$(58,246,585)	$(92,170,585)	$(125,976,575)
Depreciation Reserve	-	61,421,730	71,081,400	10,923,510	16,297,160
Interest Reserve	15,057,000	-	-	-	-
Debt Service Reserve	16,730,000	64,420,000	64,420,000	64,420,000	64,420,000
Total Cash Balance	$31,787,675	$104,532,725	$77,254,815	$(16,827,075)	$(45,259,415)

With a $5 per month *increase* in residential internet service fees, with all other assumptions remaining the same, the unrestricted cash balance would balloon, compared to the base case, and hit $234.4 million by year 20 (see table below).

Table 43: Residential Internet Fee Increases by $5 per Month

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$16,556,475	$236,831,340	$232,828,140	$232,828,140	$232,828,140
Total Cash Expenses	(14,644,140)	(95,059,610)	(92,023,430)	(92,023,430)	(92,023,430)
Depreciation	(19,524,010)	(83,441,050)	(78,874,790)	(77,234,410)	(77,234,410)
Interest Expense	(16,457,000)	(57,012,630)	(44,572,300)	(28,991,300)	(9,308,020)
Taxes	-	-	-	-	-
Net Income	$(34,068,675)	$1,318,050	$17,357,620	$34,579,000	$54,262,280

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$996,235	$40,415,535	$103,033,655	$168,665,355	$234,415,065
Depreciation Reserve	-	61,421,730	71,081,400	10,923,510	16,297,160
Interest Reserve	15,057,000	-	-	-	-
Debt Service Reserve	16,730,000	64,420,000	64,420,000	64,420,000	64,420,000
Total Cash Balance	$32,783,235	$166,257,265	$238,535,055	$244,008,865	$315,132,225

Reducing or Increasing Operating and Staffing Expenses by 25 Percent

Assuming all other factors adhere to the base case, reducing the operating and staffing expenses by 25 percent would have a substantial positive impact on cash flow. As the table below shows, unrestricted cash balance would soar to over $354.7 million by year 20 in this scenario.

Table 44: Reduce Operating and Staffing Expenses by 25 Percent (Content Fees Remain the Same)

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$16,056,195	$226,825,740	$222,822,540	$222,822,540	$222,822,540
Total Cash Expenses	(11,665,200)	(79,011,190)	(75,983,460)	(75,983,460)	(75,983,460)
Depreciation	(19,524,010)	(83,441,050)	(78,874,790)	(77,234,410)	(77,234,410)
Interest Expense	(16,457,000)	(57,012,630)	(44,572,300)	(28,991,300)	(9,308,020)
Taxes	-	-	-	-	-
Net Income	$(31,590,015)	$7,360,870	$23,391,990	$40,613,370	$60,296,650

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$3,474,895	$70,196,065	$162,990,265	$258,793,815	$354,715,375
Depreciation Reserve	-	61,421,730	71,081,400	10,923,510	16,297,160
Interest Reserve	15,057,000	-	-	-	-
Debt Service Reserve	16,730,000	64,420,000	64,420,000	64,420,000	64,420,000
Total Cash Balance	$35,261,895	$196,037,795	$298,491,665	$334,137,325	$435,432,535

On the other side of that equation, if the City's operating and staffing expenses were to rise by 25 percent over the base, the enterprise would face large deficits over time. As the table below shows, the unrestricted cash balance deficit in this scenario would be roughly $140.5 million by year 10 and over $294.2 million by year 20.

Table 45: Increase Operating and Staffing Expenses by 25 Percent (Content Fees Remain the Same)

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$16,056,195	$226,825,740	$222,822,540	$222,822,540	$222,822,540
Total Cash Expenses	(18,116,830)	(113,565,600)	(110,520,970)	(110,520,970)	(110,520,970)
Depreciation	(19,524,010)	(83,441,050)	(78,874,790)	(77,234,410)	(77,234,410)
Interest Expense	(16,457,000)	(57,012,630)	(44,572,300)	(28,991,300)	(9,308,020)
Taxes	-	-	-	-	-
Net Income	$(38,041,645)	$(27,193,540)	$(11,145,520)	$6,075,860	$25,759,140

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$(2,976,735)	$(60,685,675)	$(140,587,475)	$(217,471,475)	$(294,237,465)
Depreciation Reserve	-	61,421,730	71,081,400	10,923,510	16,297,160
Interest Reserve	15,057,000	-	-	-	-
Debt Service Reserve	16,730,000	64,420,000	64,420,000	64,420,000	64,420,000
Total Cash Balance	$28,810,265	$65,156,055	$(5,086,075)	$(142,127,965)	$(213,520,305)

High Network Implementation Costs

If implementation costs approach the high cost estimate, breaking even becomes even more challenging. The total bonding in the first four years increases to roughly $1.43 billion (from almost $1.29 billion), while the initial loan remains at $20 million. The increased bonding is from a combination of the higher construction costs and the required increase in subscribers. The take rate required to break even increases to 53 percent in year four (from 47 percent in the low FTTP cost model). The cash flow and income statement forecast for this model are shown in the table below.

Table 46: Use FTTP High Cost Estimate

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$18,109,770	$255,787,560	$251,273,160	$251,273,160	$251,273,160
Total Cash Expenses	(15,942,020)	(104,852,130)	(101,428,250)	(101,428,250)	(101,428,250)
Depreciation	(20,768,800)	(93,031,680)	(87,882,480)	(86,242,100)	(86,242,100)
Interest Expense	(17,640,500)	(63,218,610)	(49,433,340)	(32,155,680)	(10,361,920)
Taxes	-	-	-	-	-
Net Income	$(36,241,550)	$(5,314,860)	$12,529,090	$31,447,130	$53,240,890

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$965,850	$14,161,200	$45,057,100	$79,528,430	$114,200,870
Depreciation Reserve	-	72,375,750	88,838,430	34,939,740	46,567,670
Interest Reserve	16,240,500	-	-	-	-
Debt Service Reserve	18,045,000	71,565,000	71,565,000	71,565,000	71,565,000
Total Cash Balance	$35,251,350	$158,101,950	$205,460,530	$186,033,170	$232,333,540