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FTTH Design Metrics for Greenfield Deployments

Introduction

Abstract: As fiber-to-the home (FTTH) networks are becoming more widely deployed, minimizing the cost and time of that deployment has become paramount. Every design choice the engineer makes about products or installation methods has a ripple effect that extends to the financial model. Understanding these effects will enable designers to create better networks and help entrepreneurs to create more profitable businesses. To this end, the authors have created both quantitative and qualitative models to assess the merits of FTTH designs. By holding baseline factors stable and altering one variable at a time, the individual impact on cost and deployment time is demonstrated. Compounded optimization is then demonstrated by altering multiple variables, simultaneously.

New neighborhood, or greenfield, deployments represent a growing segment of FTTH networks being implemented today, affording benefits to property owners, land developers, service providers, municipal governments, and private industry. Everyone agrees that these optical fiber networks improve the quality of life for the families they serve, offering high-speed internet access, high-definition cable television, security systems, and telephone service. Land developers and FTTH providers stand to gain millions of dollars in incremental revenue when these homes sell and their inhabitants subscribe for services. Reports across the country suggest that houses/lots in neighborhoods that are FTTH-enabled fetch a $4,000 to $15,000 premium. From the standpoint of a municipality, communities that have FTTH are better poised to support economic development, primarily by attracting large businesses seeking to move to their areas. Municipalities are beginning to recommend or mandate that all new dwellings come pre-wired for broadband access, as in the City of Loma Linda, California. Ultimately, employers in communities with FTTH can cut operating costs by having some portion of their job force telecommute. As FTTH becomes mainstream, network operators are seeking to optimize FTTH design and construction.

Network Design and Business Objectives

Every access network is an access business. An ideal design offers that business:

1. Minimal Initial Investment. In order to best leverage funding and resources, designs offering the lowest initial cost to pass homes (but not to connect them) should be used. This will use the smallest resource in preparation for connecting subscribers and generating revenue.

2. Delayed Deployment Costs. Postpone network costs, usually subscriber connection labor and material costs, until the connection is needed. This will scale the greatest amount of the cost with the generation of revenue, producing the best possible cash flow.

3. Minimal Future Costs. This includes minimizing the subscriber connection cost, as well as future proofing for technological advances and network expansion.

Design Evaluation Objectives

Every design decision has an impact on either cost, or deployment time, or both. The goal is to minimize both. Understanding how each design decision impacts material and labor costs, time to deployment, and finance costs, will enable an engineer to achieve design optimization. This paper aims to demystify this process by evaluating designs on quantitative and qualitative elements. In particular, this paper analyzes the impact of "heavy hitters" (choices that dramatically affect the bottom line) in the design decision process. Design choices over which network engineers have control are evaluated, as well as several non-FTTH design parameters.

Design Evaluation Methodology

Ideally, one could evaluate a network design in several categories, apply weight to these factors, and then total these into a final score or "grade." We recognize, however, that such an approach, while attractive, can produce good relative scores that do not address finer points, such as future-proofing, that must be part of any network business strategy. For this reason, this paper considers a handful of metrics to evaluate a design, relative to both short and long-term business objectives.

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In order to perform a comprehensive analysis, we created a computer model that considers the major choices facing a network design engineer, shown in Fig. 1.

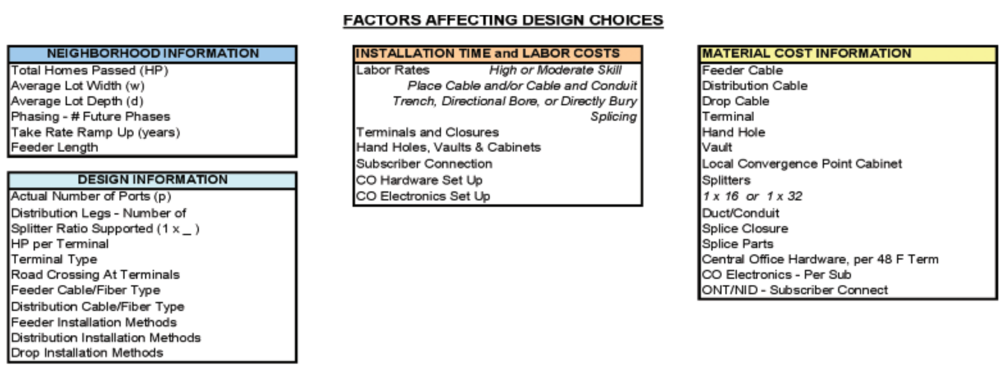

Figure 1 – Design Elements

The overall evaluation of any network design must consider both the quantitative and qualitative aspects of the network. It must meet short-term goals, such as minimal initial investment and quick profitability. In addition, to be a long-term business, it must be future-proofed against changes in transport technologies and customer needs. The quantitative evaluation is primarily technical and financial in nature. The qualitative evaluation balances the quantitative evaluation with factors that may not be considered in a cost analysis–or may even be contrary to minimizing cost–but which are important to the longer term objectives of the network and business owners.

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Elements of the Quantitative Analysis include:

- **Initial Investment.** This is the cost of deploying feeder and distribution components, making it possible to quickly connect subscribers and generate revenue. Initial construction is directed at passing homes. The investor(s) realize this cost in a short time, up-front, before generating revenue.
- **Subscriber Connection Cost.** This is the cost of connecting subscribers when they request services, usually upon move-in of the newly constructed residence. This cost is realized over the course of building out the homes in the neighborhood, and may be spread over several years.
- **Total Project Cost.** Taken as a whole, the total cost for material and labor merely reveals the entire investment required to construct the network and connect subscribers.
- **Investment Ratio.** In order to align cost with revenue generation, it is desirable to defer as much cost as possible to the subscriber connection phase, minimizing the initial investment required to deploy the network. This is a beneficial practice, provided it does not cause the present value of deferred activities to be traded for significantly higher cost activities in the future.
- **Deployment Time.** This factor must be examined equally in both the initial deployment and subscriber connection phases. Faster initial deployment increases the rate at which homes can be passed and therefore the potential to connect subscribers and generate revenue. Network operators must also minimize connection time per subscriber, enhancing customer satisfaction and supporting high demand.
- **Finance Costs.** Whether a project is financed internally or externally, through private investors or financial institutions, there is some expected rate of return for the entity supplying the capital. Using a loan amortization model, this real cost can be factored into the analysis of how each design decision impacts the bottom line. Examples will follow later in this paper.
- **Cash Flow.** All design decisions, as well as finance costs, will impact cash flow, ultimately determining when a break-even state is achieved. Cash-flow analysis provides a realistic measure of how design choices affect profitability.
- **Non-FTTH-Design Factor.** Factors that are not necessarily under the control of the network engineer do, nonetheless, impact the deployment costs and cash-flow picture for the network. Lot frontage (width) and take rate ramp-up are modeled herein to demonstrate the impact of such non-FTTH-design factors.

Elements of the Qualitative Analysis include:

- **Architecture:** The system architecture determines how the various network components (fiber paths, hubs, terminals, splitters, and electronics) relate to each other logically. A homerun architecture, taking each subscriber's fiber path back to the central office or remote terminal, is given a full score (100), because this system would be most amenable to change. A local convergence model, where splitters are placed in a single neighborhood location, is given a near full score (90), for its cost-reduction benefits with hardly any future-proofing sacrifice compared to the homerun architecture. A distributed splitting architecture, where there are two or more tiers of splitters feeding each other, is given no score (0) because of its large potential to significantly limit future network management and upgradeability.

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- **Splitter Ratio Supported:** The supported ratio represents the lowest split ratio for which there is sufficient fiber; it typically is numerically smaller than the working ratio of the system. Systems capable of a 1x16 split or smaller (such as a 1x8) for each subscriber, receive full points (100). Systems that can support lower than 1x32, but not 1x16, receive 90 points. Systems designed for exactly 1x32 splits, but no lower, receive 80 points and those that are designed for split ratios of greater than 1x32 (which could occur with active devices in the field) are awarded 0 points, due to their inability to support a passive optical network (PON) to every home passed.
- **Fiber to the X:** True FTTH networks, receive 100 points on this metric, whereas networks that support fiber to the curb (typically 8 to 24 subscribers per active device) receive just 50 points and those that support fiber to the node (typically more than 24 subscribers per node) receive 25 points. Non-FTTH systems earn reduced points because they have reduced bandwidth, ultimately requiring some amount of system overbuild in order to keep pace with service demands.
- **Triple-Play-Plus Compatibility:** FTTH is truly the ultimate network, but unless one considers certain parameters, such as fiber type, splitter ratios, distance, attenuation, and, especially, reflectance, the ability of an FTTH business to offer a wide variety of services may become limited. Installing angled physical contact connectors, which limit reflectance, such as SC APC connectors, at all connectorized locations scores 100 points. Angled connectors in a system accommodate not only voice and data, but also various forms of video, including RF video overlays and IP-based formats. Designs using only ultra polish connectors (UPCs) are awarded 30 points because they may restrict the choice of electronics vendors.
- **Standards Compatibility:** Again, future proofing is considered here. Standards proposed and offered by the ITU-T (FSAN) and IEEE (Ethernet) organizations offer minimum performance levels that will help ensure compatibility with future technology changes. Designs that are not within these standards may or may not be easily updated in the future. Compliance to both standards scores 100 points, with one standard scoring 85 points and with no standard scoring 0 points.
- **Transparent Technology:** This metric applies not just to the fiber part of the network, but the electronics, as well. Electronics that are capable of providing an acceptable quality of service for offerings such as voice and video are awarded 100 points, whereas systems with only limited or no such provision receive no points.
- **Maintainability & Environmental Robustness:** This metric is a measure of how easily and quickly the system can accommodate maintenance and repairs, as well as its ability to avoid damage from natural and human-made sources. One of the most likely parts of the network to be damaged is the drop cable. Precautions such as burying the cable deeper than required or using toneable drop cable shall earn 100 points here. Conduit also allows for simple drop replacement, should it be required. Designs that minimize drop length also lend themselves to easier troubleshooting and maintenance. Installations that make no provision for prevention and repair score 0 points.
- **Resale Attractiveness:** When developers or small service providers build FTTH networks, they should consider what attributes will facilitate the integration of the network into a larger provider's system, thereby enhancing its attractiveness for a buy-out, should that be or become a desired business objective. Attention to splitter ratio, architectural selection, and industry standards will enhance network value in this regard. Networks that are designed around the home run or local convergence models and support split ratios and standards compliant with the operations of a different future service provider are awarded 100 points. Those that meet most of a potential purchaser's operating practices are awarded 80 points and those that meet few, if any, or which use products and practices not recognized in the industry are awarded 0 points.

Quantitative Modeling and Analysis

In order to evaluate network designs based on the quantitative aspects outlined above, we created a model that incorporates a variety of design choices, as shown previously. An optimized design is one that minimizes cost and maximizes profit. Most importantly, this model considers the impact of each product choice and distribution method as it relates to material cost, labor cost, and deployment time.

While we examined many design choices, several heavy-hitting parameters significantly reduced cost. They include: terminal port count (sizing), dedicated vs. joint trenching, and trenching vs. boring. In many cases, a given choice creates a ripple effect. For example, using a larger port-count size (12, instead of four, for example) on the network access point terminal results in longer drop cables that require more installation time and labor. This analysis also includes several factors that are not necessarily within the network engineer's control, but which have an important impact on the network business model, including lot frontage (width) and take rate ramp-up period. The final analysis shows a best and worst case design comparison to illustrate the positive effect of compounded optimization.

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Baseline Design Assumptions

In order to evaluate each design parameter individually, the model begins at "baseline design settings." This enables the user to evaluate the net effect of changing a single design parameter. The baseline settings include:

Design Parameter	Baseline Setting
Homes Passed	400
Lot Frontage	75 Feet
Lot Depth	100 Feet
Take Rate Ramp Up	5 Years
Feeder Length	1.5 miles
Actual # Ports Deployed	424
Terminal Size	4 Ports/Terminal
Feeder Cable Type	Loose Tube
Distribution Cable Type	Loose Tube
Feeder Installation Method	Dedicated Trench w/Conduit, 10% Boring
Distribution Installation Method	Dedicated Trench w/Conduit, 10% Boring
Drop Installation Method	Direct Buried, 10% Boring
Cost of Capital	7% Annual Rate
Network Revenue	Typical Suite of voice, video and data services totaling $110/subscriber, less content and connect costs.

Figure 2 – Baseline Settings for Quantitative Model

Terminal Port Count

FTTH terminals for connectorized drop cables typically come in four, eight, and 12-port units. The use of higher count terminals is attractive for minimizing material costs (terminals, hand holes) and labor costs (mid-span access on cables) in the initial investment phase of deployment. However, for other than very high population densities, high-count terminals usually mean that drop cable length and installation time must increase to account for the fact that there are fewer terminals to which to connect. There are immediate cost considerations here (material and labor) as well as deferred considerations for future maintenance and subscriber connection speed when a new service order is implemented.

First, using 75-foot building lots, the analysis shows that while initial cost declines as port count increases, the cost of subscriber connection increases more rapidly, offsetting the initial savings and resulting in a higher net material and labor cost. In our 400-home example, the added cost from four- to 12-port terminals is about $80,000. The corresponding finance costs add $15,000, for a total incremental amount of $95,000—a 12% increase—in operating costs for using 12-port terminals instead of four-port terminals.

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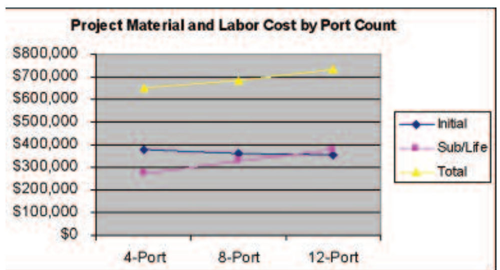


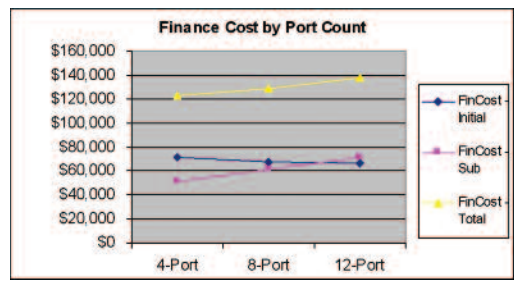


Figure 3 – Differences in Project Costs Due to Port-Counts
Figure 4 – Differences in Finance Costs by Port Count

Furthermore, the impact on annual cash flow is important, too. Here we see that at year five, when most deployment will have already occurred, there is about a $19,000 difference on this development. A long-term cash flow analysis shows the design decision to be worth nearly $100,000 over 15 years.

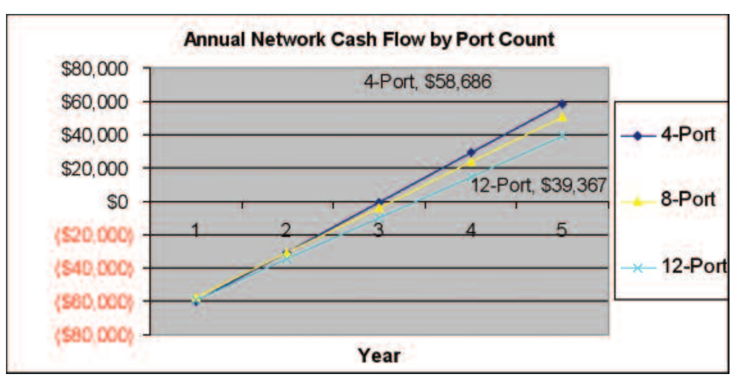
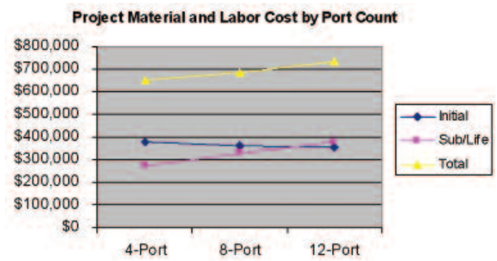


Figure 5 – How Port Count Affects Cash Flow

Besides the financial analysis, the system deployment time is also affected.



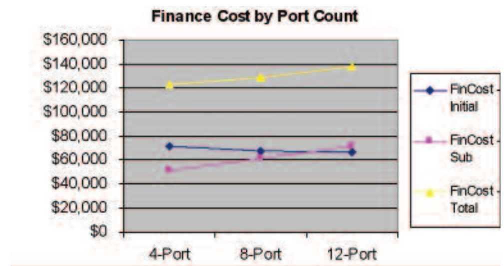


Figure 6 – How Terminal Port-Counts Affect Total Project Implementation Time
Figure 7 – How Terminal Port-Counts Affect Subscription Times

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Most telling is the connection time per subscriber. The four-port terminal's short drop lengths permit a technician to connect two to three subscribers per day (including mounting the equipment at the house), while the 12-port terminal accommodates less than two connections per day due to the longer drop lengths.

An analysis of the same scenario using 150-foot lot frontages would show a similar, but magnified, relationship, where the cash flow graphs for each design choice more readily diverge. Project material and labor costs are nearly $200,000 more for the 12-port terminals than for the four-port terminals. In this 400-home development, the FTTH business with four-port terminals breaks even eight months sooner than with 12-port terminals. In long-term cumulative cash flow, the 12-port scenario lags by about $222,000. Again, as with the 75-foot lot frontages, the longer drops required for 12-port terminals greatly increase deployment times.

Dedicated vs. Joint Trenching

Prior to home construction, developers must build infrastructure for water, sewer, gas, and communications. When these utilities are installed into the same trench, the builder can realize significant cost savings. Analysis of this parameter considers four combinations of cable placement methods for feeder and distribution:

Feeder	Distribution	Scenario
DT/C	DT/C	**D**edicated **T**rench w/**C**onduit for Both
DT/D	DT/C	**D**edicated **T**rench w/**D**irect Buried Feeder, Conduit for Distribution
DT/D	JT/C	**D**edicated **T**rench w/**D**irect Buried Feeder, Joint Trench (40% share) w/Conduit for Distribution
JT/D	JT/C	**J**oint **T**rench (40% share) w/**D**irect Buried Feeder, **J**oint **T**rench (40% share) w/**C**onduit for Distribution

Figure 8 – Cable Placement Combinations

Using joint trenching, as well as the use of directly burying feeder cables, offers an opportunity to reduce the initial investment costs by nearly 9%, without any significant impact on future subscriber connection costs, as illustrated here:

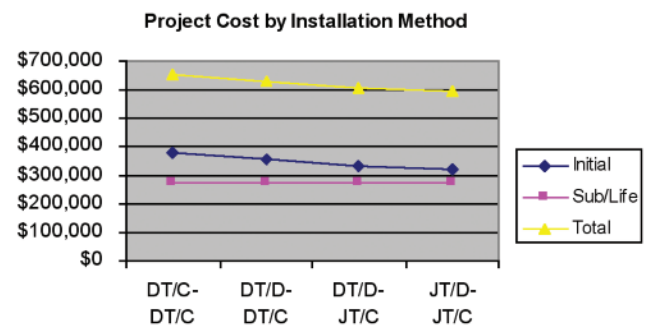

Figure 9 – How Project Costs Vary By Cable Placement Methods

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From a cash-flow standpoint, the joint trenching represents an earlier breakeven point in this 400-home example. Over a five-year period, cumulative cash flow is improved by approximately $67,000.

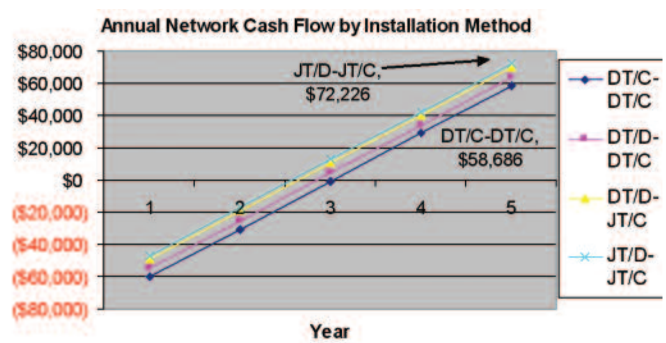
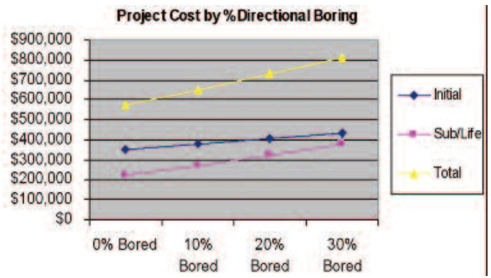


Figure 10 – How Cable Placement Methods Affect Annual Cash Flow

Trenching vs. Directional Boring

Directional boring is an excellent technique for installing cable under roadways and landscaped areas, because it requires little restoration; if done correctly, the installation maintains original surface conditions. However, it is also the most expensive installation method to perform, per foot. In a new neighborhood setting, it should thus be employed sparingly. As an across-the-board comparison, we compared the use of 0-, 10-, 20- and 30-percent boring as an installation method, to understand the cost impact on the project.



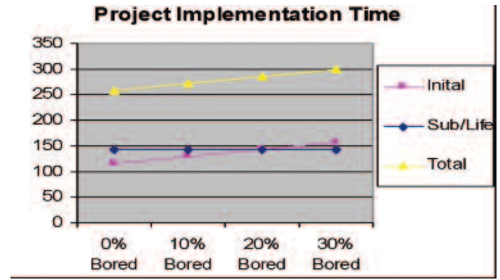


Figure 11 – How Directional Boring Affects Project Costs
Figure 12 – How Directional Boring Affects Project Deployment Time

Implementation time was affected mainly on the feeder and distribution segments. Project cost increased by about $240,000—nearly 42%—when increasing directional boring from 0% to 30%. Subscriber connection time was not affected, as the model assumes slower techniques for drop cable placement. Greater use of directional boring significantly reduced cash flow, delaying the break-even point by nearly two years. A cumulative reduction in cash flow of about $285,000—nearly 14%—is realized by the tenth year of operation.

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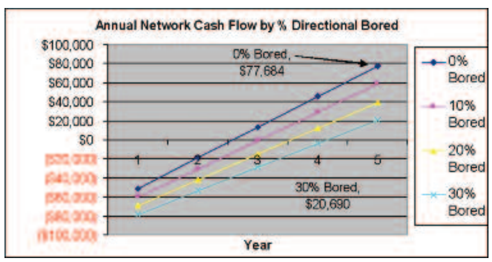

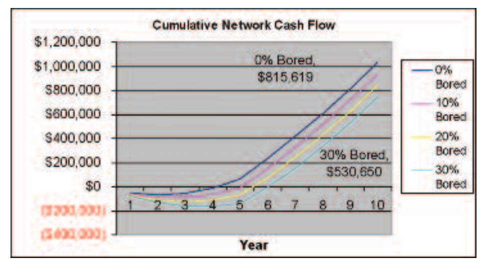

Figure 13 – Impact of Directional Boring on Annual Cash Flow
Figure 14 – Impact of Directional Boring on Cumulative Cash Flow

Lot Frontage

While lot frontage decisions are the prerogative of the developer and not the network design engineer, early coordination between them can optimize the FTTH network. As shown below, project costs increase as lot frontage increases, with all other factors held equal.

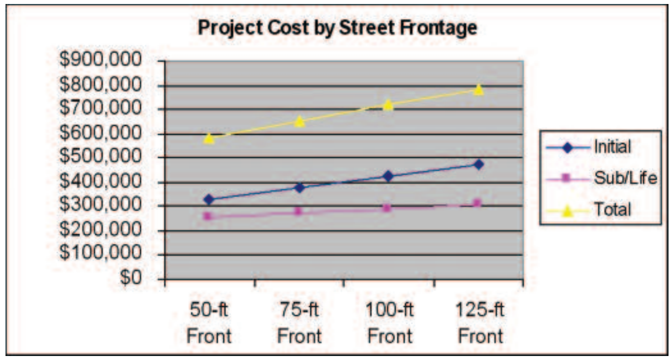

Figure 15 – How Lot Frontage Affects Project Costs

Project implementation time, as well as subscriber connection time, is affected by increasing lot frontage, due to the fact that longer distribution and drop cables are required.

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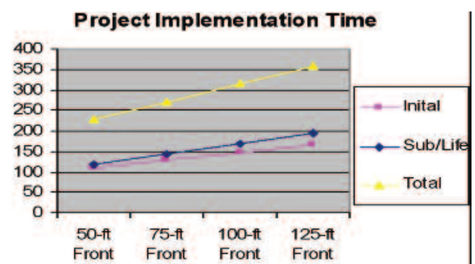


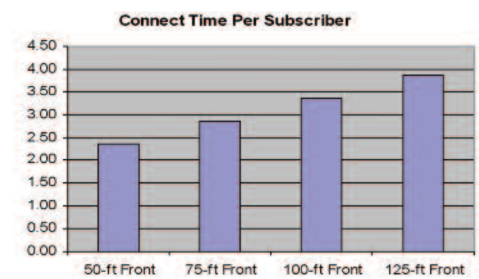
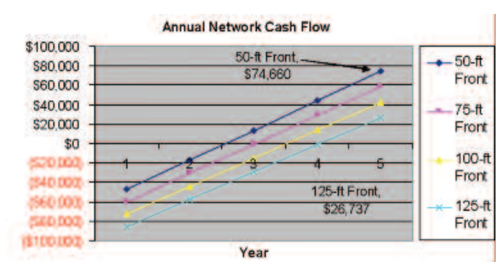


Figure 16 – How Low Frontages Affect Project Implementation Time
Figure 17 – How Lot Frontage Affects Subscriber Connection Time

Cash flow is affected, as well as breakeven points. In the long-term picture, the difference in cumulative cash flow between 50-foot lots and 125-foot lots is approximately $240,000 – nearly 12% – for our scenario.



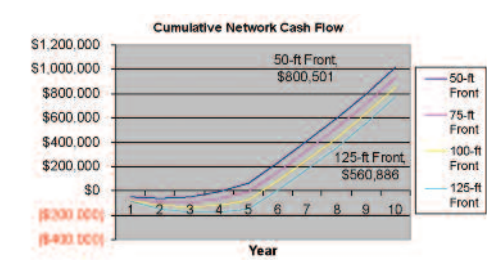


Figure 18 – The Affect of Lot Frontage on Annual Cash Flow
Figure 19 – The Affect of Lot Frontage on Cumulative Cash Flow

Take Rate Ramp-up Period

The impact of quickly completing the network and subscribing the neighborhood is significant. This requires a strong marketing campaign and clearly depends on outside factors such as a robust real estate market. However, the quick build-out saves not only finance costs, but also enables significant revenue much earlier in the cycle. Below, the finance cost difference for the same construction project is about $74,000 for a two-year vs. five-year build-out period—a 152% increase in finance costs, or about 11% greater total project cost.

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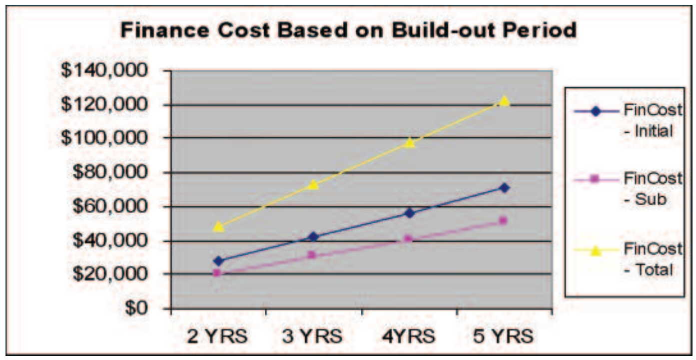
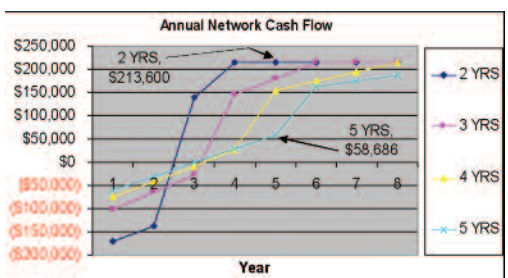


Figure 20 – How Build-Out Period Affects Finance Costs

In terms of annual cash flow, the faster build-out produces a much earlier breakeven point and higher profitability. In the long term cumulative picture, the faster two-year build-out is worth about $394,000 compared to the five-year build out.



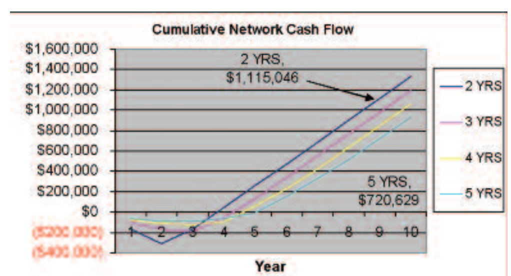
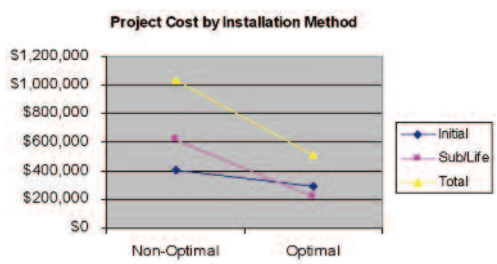


Figure 21 – How Build-Out Periods Affect Annual Cash Flow
Figure 22 – How Build-Out Periods Affect Cumulative Cash Flow

Best and Worst Case Examples

To illustrate the synergy of optimizing multiple design decisions, we created "Best Case" and "Worst Case" scenarios. In the Worst Case scenario, we used twelve-port terminals, along with all dedicated trench and conduit, plus 30% directional boring. In the Best Case scenario, we used four-port terminals, along with directly buried feeder cable in a joint trench (30% cost share), distribution cables in conduit in a joint trench (30% cost share), with directional boring restricted to 5% in the feeder segment. While most installations will fall somewhere in the middle of these two extremes, the example illustrates the immense potential for compounded cost reduction.



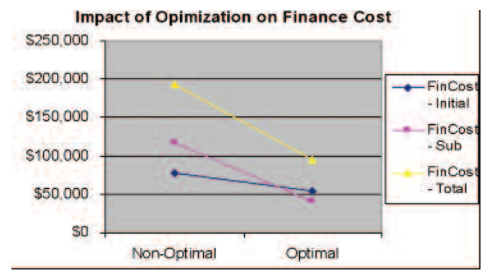


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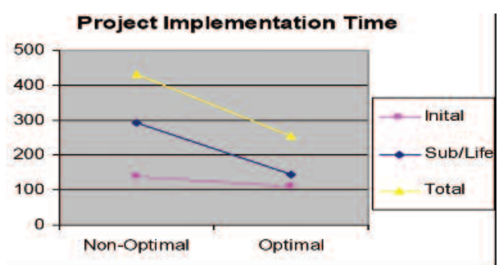
Figure 23 – Project Costs for Best and Worst Case Scenarios
Figure 24 – Finance Costs for Best and Worst Case Scenarios

The cumulative effects of these cost-saving decisions permit the business owner to pass even more homes with fewer resources, allowing more subscribers to be connected in less time.



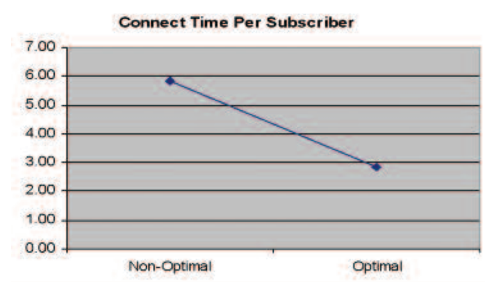


Figure 25 – Project Implementation Times for the Best and Worst Case Scenarios
Figure 26 – Subscriber Connections for Best and Worst Case Scenarios

With the same service pricing structure, optimization ensures an earlier break-even point based on annual cash flow analysis. Over a ten-year period, more than half a million dollars is realized in additional cumulative cash flow.

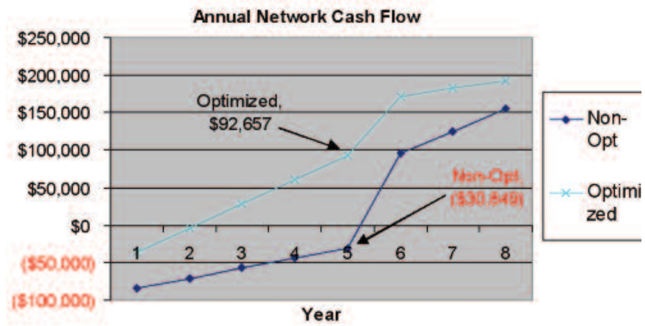


Figure 27 – Annual Cash Flow for Best and Worst Case Scenarios

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Qualitative Scoring System Model

The qualitative scoring model tallies up the grade on each design element. It forms a complete checklist that ensures that the designer and business owner consider these non-quantitative elements.

QUALITATIVE ANALYSIS

		Score			Score
ARCHITECTURE USED			**BANDWIDTH/TRIPLE PLAY + COMPETITIVE**		
			Have sufficient Fiber Type, Splitter Ratio, without excessive Distance, Attenuation, or Optical Return Loss?		
Central Switch Home Run	**1.00**		***Yes***	**1.00**	
Local Convergence	0.90		*No*	0.00	1.00
Distributive Splitting	0.00	1.00			
SPLITTER RATIO ACCOMMODATED (FIBER COUNT)			**STANDARDS COMPLIANCE**		
1 x 16	**1.00**		***Both FSAN and IEEE***	**1.00**	
1 x 24	0.90		*FSAN only*	0.85	
1 x 32	0.80		*IEEE only*	0.85	
> 1 x 32	0.00	1.00	*Neither*	0.00	1.00
FIBER TO THE ______			**TRANSPARENT TECHNOLOGY**		
Home/Premises	**1.00**		*Is infrastructure suitable for other applications?*		
Curb	0.60		***Latency Tolerant***	**1.00**	
Node	0.40	1.00	*Some Tolerance*	0.50	1.00
MAINTAINABILITY & ENVIRONMENTAL ROBUSTNESS			**RESALE ATTRACTIVENESS**		
Excellent	**1.00**		*Excellent*	1.00	
Good	0.80		***Good***	**0.80**	
Poor	0.00	1.00	*Poor*	0.00	0.80
DESIGN QUALITY SCORE					
60% Architecture, Splitter Ratio, and Fiber-to-the ______					
40% Bandwidth, Standards, Transparency, Maintainability, and Resale Attractiveness					0.98

Figure 28 – Annual Cash Flow for Best and Worst Case Scenarios

Summary and Conclusions

The evaluation of any network design must incorporate a multitude of factors within a framework that addresses both short-term and long-term business objectives. The quantitative evaluation addresses primarily short-term implementation-related factors in detail, yet provides a long term picture of financial health. The quantitative evaluation shows clearly that each engineering (technical) decision has a direct impact on the financial viability of the network. The qualitative scoring system addresses primarily long-term concerns and acts to balance out the "pay me now or pay me later" nature of design decisions. The qualitative evaluation, while seemingly simple compared to the quantitative evaluation, is nevertheless just as critical, as it ensures the long-term viability and upgradeability of the network. Therefore, network owners, investors and managers must be comfortable with the results of both analyses before funding construction projects to build FTTH networks.

We recognize that our analysis makes assumptions about labor rates and practices, which may vary from one company or geographic region to another. Nevertheless, the underlying principles are the same. We have evaluated only a handful of possible network decision points. Other choices, such as the use of ribbon vs. single fiber cables or the choice of pulling terminal branches vs. individual drops across streets will also have significant effects. Design choices that produce only a couple of dollars per home passed may seem trivial in the 400-home project showcased here. However, when passing hundreds of thousands of homes or even a million homes in a year, a few dollars saved on each home passed can easily become several million dollars saved. Not only is the cost of deployment of key concern, but deployment velocity is just as important. In the face of competition, the ability to rapidly pass homes and quickly connect them when service is needed is a critical strategic element for service providers. To this end, new product innovations are improving deployment velocity–and FTTH products will continue to evolve in the years to come.

notes |

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