Fibre-to-the-Premise Cost Study

Prepared for

The Treasury

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Executive Summary

The cost for deployment of a fibre based access infrastructure for urban New Zealand has become a topic of considerable interest. Many commentators have offered cost estimates, based on either international experience or rough analysis of the New Zealand situation. However, few of these previous analyses have provided detail on the assumptions used to derive the figures and hence the basis for the offered numbers is poorly founded. It is even hard to determine what the figures quoted actually mean in many cases.

There are many parameters which can be used to define the costs involved, including:

- Cost per premise passed,
- Cost per premise connected,
- Investment required to pass a defined market segment,
- Investment required to connect a defined market segment.

Each of these parameters defines a distinctly different view of the costs involved. Furthermore, given the large number of variables involved, it is hard to believe that a single number for any of the above parameters could be defined in a realistic manner. If a number is defined, is it an average, maximum or minimum?

A more realistic approach to defining the cost is based on a modeling approach using a set of defined assumptions, which generate a range of variables. These variables can then be used to define the likely range of values which could be expected from a realistic deployment of fibre based technology across a defined geography and population density. The analysis which is described in this report takes this approach. Obviously, the number of variables is enormous in practice and so in order to constrain the size of the modeling task, only the most significant variables have been investigated. Hence in this context, the model used in this study is also limited. However, the range of values derived from the model does provide a useful estimate of the likely range of values to be expected in practice.

The models that were investigated used two different technologies for the deployment: Passive Optical Networking and Active Ethernet over Fibre. For each of these technologies, the following cost components have been analyzed separately:

- Fixed passive infrastructure costs
- Variable passive infrastructure costs

- Variable active component costs.

For each of these components, the key variables have been defined and included in the analysis. Then all of the components have been combined to provide a set of aggregate values based on a set of clearly defined assumptions. In addition, the costs have been broken down into those attributable to the service provider and those attributable to the consumer. Finally, the aggregate figures provide a sound basis for the derivation of both unit costs and overall investment required to provide a defined coverage and take-up of service within that coverage area.

The results for a G-PON deployment to cover 75% of premises located within urban New Zealand can be summarized as follows:

- The fixed passive cost per home passed can be expected to lie in the range of $1700 to $2400,
- The variable passive cost per home connected can be expected to lie in the range of $800 to $1200,
- The variable active cost per premise connected can be expected to lie in the range of $1200 to $2400,
- The fixed passive investment required for coverage of urban New Zealand premises (75% of NZ premises) can be expected to lie in the range of $2.6B to $3.3B
- The total investment required for connection of urban New Zealand premises with a take-up of 100% within the coverage area can be expected to lie in the range of $5B to $7.5B.
- The total investment required for connection of urban New Zealand premises with a take-up of 50% within the coverage area can be expected to lie in the range of $3.5B to $5.5B

The results for the AEF deployment are similar to those for the G-PON deployment except that:

- The fixed passive infrastructure unit costs and investment are about 5% higher than that for G-PON,
- The active infrastructure unit costs and investment are about 10% higher than that for G-PON,
- The total infrastructure unit costs and investment are about 15% higher than that for G-PON.

This study also shows that:

- It is very challenging to achieve a premises passed unit cost of substantially less than $2000, even using low cost deployment techniques to the greatest extent possible,

- The government's proposed investment of $1.5B will provide about 50% of the investment required to deliver fibre passed 75% of New Zealand premises,
- The cost of connecting a premise remains a substantial component of the total cost of deployment for FTTP, even after the premises have been passed by fibre infrastructure.

Given the above analysis, it is obvious that the lowest possible deployment costs are required for the passive components of the infrastructure, consistent with sound deployment practices to minimize investment in a FTTP rollout for New Zealand. This suggests the need to maximize the use of the lowest cost deployment techniques, including:

- Aerial,
- Micro trenching and
- Intelligent directional drilling (a very new approach).

Based on this need it is recommended that:

- A uniform policy be established for the use of aerial plant across New Zealand urban areas, which clearly defines where aerial plant can be used and where it cannot,
- A set of best practice guidelines be established for aerial deployment, where aerial plant is available for use,
- A pilot of micro trenching be funded by Central Government to determine the best practice guidelines to be applied nationwide,
- The applicability and costs for intelligent directional drilling be investigated thoroughly and then be reflected into updated cost models.

In addition to the above, it is recognized that the current models still have significant limitations in terms of an accurate assessment of the likely cost of providing an FTTP solution to the lowest cost 75% of premises in New Zealand. In order to further improve the accuracy and usefulness of the modeling, one would need to take another step towards the detailed design of a fibre rollout. This would involve dividing the coverage area into blocks, each of which had some consistency in terms of deployment characteristics – for example blocks suitable for mainly aerial deployment or mainly micro trenching. Then a first order optimal design could be done for each block. Furthermore, as with an actual rollout, blocks could be selected on the basis of cost for inclusion into the final coverage area, in order to determine the cost for deployment to the lowest cost 75% of premises in New Zealand. This approach could readily be implemented with known data sources, but would take at least an order of magnitude more time to complete than the current exercise. In order to achieve this goal, it is recommended that:

- A more detailed cost modeling exercise be undertaken based on a block based high level solution design, in order to identify the investment required to serve the lowest cost 75% of premises in New Zealand,

It be recognized that such an exercise will cost some hundreds of thousands of dollars to complete.

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1. Introduction

[Withheld under section 9(2)(f)(iv) of the Official Information Act]

2. Background

The estimate of costs for the deployment of a Fibre-to-the-Premise (FTTP) access architecture for New Zealand is fraught with difficulty, due to the many variables and assumptions involved in any such analysis. In this analysis, an attempt is made to expose most of the underlying assumptions and variables and assess their impact on the resulting cost assessment. The analysis will also attempt to draw out the various components of the cost into categories, including:

- Fixed and variable,
- Active and passive,
- Service Provider and customer.

This study investigates all of these factors and identifies the likely range of values for each based on a relevant set of assumptions for the implementation of each factor. When all of these variables are combined we find that the actual cost of FTTP deployment for urban New Zealand is subject to considerable variability, depending on the mix of assumptions chosen.

In reality, the New Zealand urban environment is not homogeneous in terms of:

- Deployment conditions,
- Section dimensions,
- Dwelling locations within sections,
- Types of dwelling deployed,
- Condition of in-premise cabling,
- Types of services required per dwelling,
- Etc.

Hence it will never be possible to determine a single value for the cost of Fibre-to-the-Premise deployment for New Zealand. Any figure quoted is at best an estimate based on some form of massive averaging and can only be used as a guide. The enhancement provided in this report is that an attempt is made to define the likely range of values that might be encountered under realistic deployment conditions and taking into account the variations in premise topography and requirements. In reality a range of these factors will occur in different localities throughout New Zealand and so we can expect the costs for deployment to vary considerably by location. The big challenge in estimating the average values is our understanding of the distributions of the different variables. Unfortunately, there is little information available to help with any form of comprehensive statistical analysis.

3. Definitions

The first issue which must be addressed is to clearly define the problem that is being addressed. Many related studies address specific aspects of the problem and often do not fully define the context of the specific aspects being addressed.

3.1.Fibre-to-the-Premise (FTTP)

FTTP in this report is used to define the generic provision of fibre optic based technology to provide a telecommunication capability all the way into the consumer's premise, with the optical to electrical conversion being implemented on the consumer premise. FTTP is used independent of whether the consumer is a business or residential consumer. The total set of FTTP solutions can be subdivided into two subsets based on type of customer, such that:

- Fibre-to-the-business (FTTB) refers to the provision of fibre based access solutions into premises occupied primarily for business purposes, and
- Fibre-to-the-home (FTTH) refers to the provision of fibre based access solutions into premises occupied primarily for residential purposes.

Naturally, in the New Zealand environment, there are many premises which are used for a combination of business and residential purposes in the Small Office/Home Office (SOHO) context, so that there is a blurring between these two subsets that needs to be recognized. To the greatest extent possible, the definitions of business and residential premises as defined by the Department of Statistics will be used in this study.

The other key discrimination factor between FTTP access solutions is the differences in architecture which can be used for implementation. These include two primary categories as follows:

- Active Ethernet Over Fibre (AEF),
- Passive Optical Networking (PON).

The AEF implementation involves point to point fibres deployed from some central location out to each individual premise being provided with service, as illustrated in Figure 1. Each individual fibre pair (typical configuration, although single fibre feed can also be used) will be fed via an Optical Line Terminal (OLT) located at the central location which acts as a point of aggregation and is often referred to as the Central Office (CO). At the consumer premise, the fibre will be terminated in an Optical Network Terminal (ONT) which is dedicated to each premise. In this configuration, the fibre pair is dedicated to a single consumer premise and there is no sharing of the fibre resource. This includes the dedicated use of optical to electrical and electrical to optical conversion at each end of the dedicated pair of optical fibres.

In a multi-tenant premise, the AEF architecture can be used to deliver service to multiple consumers, located in the same physical premise (such as a high rise building) over a single pair of fibres. In this case, the ONT is used to provide individual ports for each consumer within the multi-tenant premise. In this case the bandwidth derived from the fibre access is shared across the number of ports configured, and can result in contention for the available resource depending on how the OLT-ONT circuit is configured. In the New Zealand context, multi-tenant residential buildings are not common and so this form of shared infrastructure architecture is not specifically considered in the cost models.

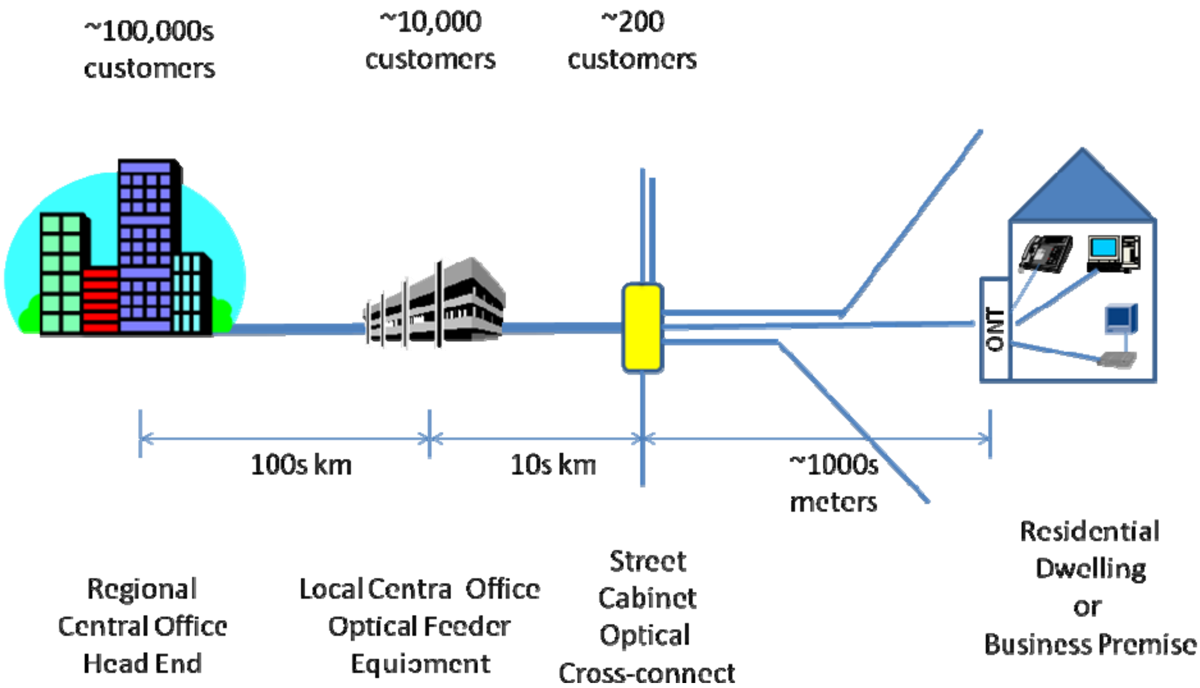

Figure 1: Typical Active Ethernet over Fibre architecture.

In comparison, Passive Optical Networking (PON) deliberately involves the sharing of the deployed fibre resource across a defined number of consumer premises, as illustrated in Figure 2. The feeder part of the access fibre is shared across 32-64 (typical) consumers, while the short distribution component only is dedicated to each consumer. Passive optical splitters are deployed in the route to the customer to enable the splitting and combining of the optical capacity between the consumers. A two level splitting architecture is typically used to enable the minimization of the fibre deployed in the distribution architecture. It is assumed that the splitter architecture will have a maximum utilization of about 80% as it is very difficult to achieve much better than this in practical deployments.

PON comes in many forms and is continuing to evolve. The primary PON architectures available today and likely to be available in the future include:

- Broadband Passive Optical Network (B-PON),
- Ethernet Passive Optical Network (E-PON),
- Gigabit Passive Optical Network (G-PON),
- Next Generation Passive Optical Network (NG-PON)

- Wavelength Division Multiplex Passive Optical Network (WDM – PON).

Of these, the G-PON architecture is being most widely deployed today with 64:1 splitting being most common. Most recent cost studies involving PON use this architecture. In the future, the NG-PON architecture will become more prevalent and in the longer term (during the next decade) the WDM-PON architecture is likely to become popular.

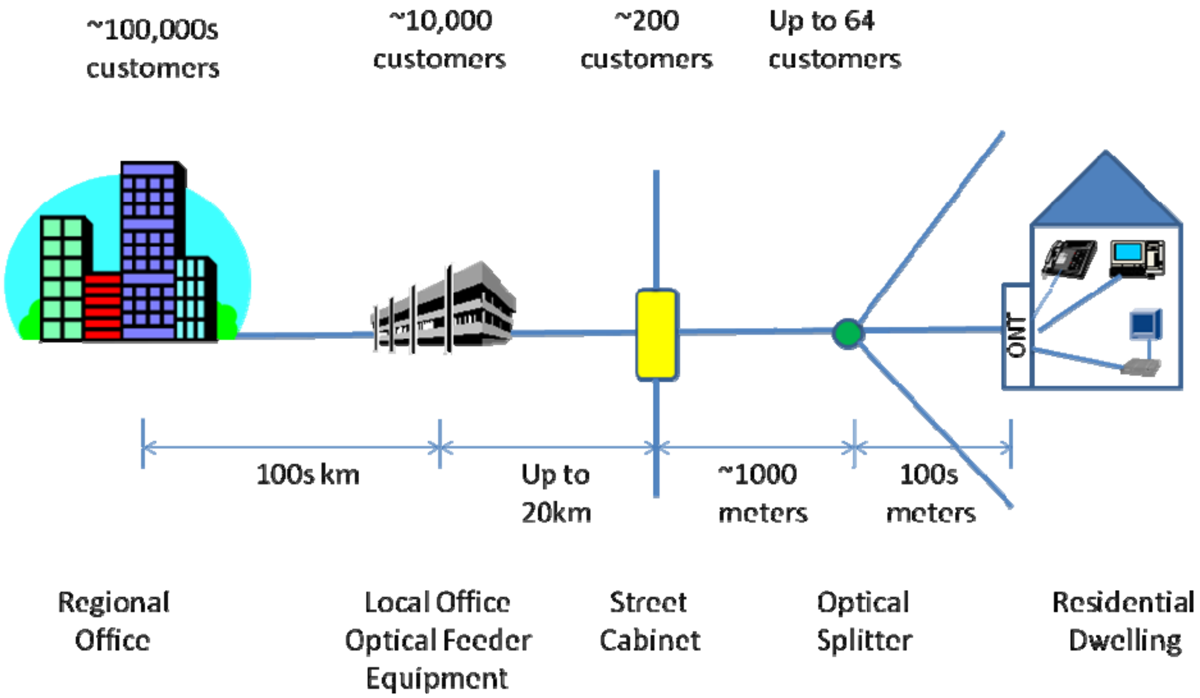

Figure 2: Typical Passive Optical Network Configuration using the G-PON technology.

The PON architecture is best suited to the residential consumer environment and so is frequently used for deployments of FTTH. On the other hand, the AEF architecture is more frequently deployed for business applications or FTTB. The AEF architecture is also widely used for the provision of service into multi-tenant high rise residential dwellings as mentioned above.

FTTP today is deployed widely into business premises using the AEF configuration. Coverage of business premises in high density areas such as the CBDs of cities is widely available. Coverage is progressively moving out into the suburbs to provide service to business premises in less densely populated areas, again typically using the AEF configuration. In some countries such as Singapore and Hong Kong, there has also been increasing deployment of the AEF FTTP architecture into high rise residential apartment buildings.

On the other hand, FTTP is increasingly being deployed to deliver service to residential premises in new residential sub-divisions. This is often referred to as "greenfields" FTTH deployment. To date, there has been much less deployment of FTTH to replace existing copper cable networks, in what is often referred to as "brownfields" deployment situations. The big difference between "greenfields" and "brownfields" deployment is that in the case of "greenfields" deployment, the ground is developed with other services such as roads, footpaths, sewage and utilities, so burial is a relatively simple process and hence low cost. In some situations, a greenfields developer will provide the trench at zero cost as part of the development. However, the greenfields situation is a very small part of a major rollout of FTTP, so will not be considered specifically in the analysis which follows.

3.2. Fibre–to-the-Node (FTTN)

The other fibre based architecture which is becoming widely deployed around the world is fibre-to-the-node (FTTN). This architecture has fibre deployed in the feeder of the access network as illustrated in Figure 3, but uses the existing copper twisted pair cable network to deliver the service into the consumers' premise.

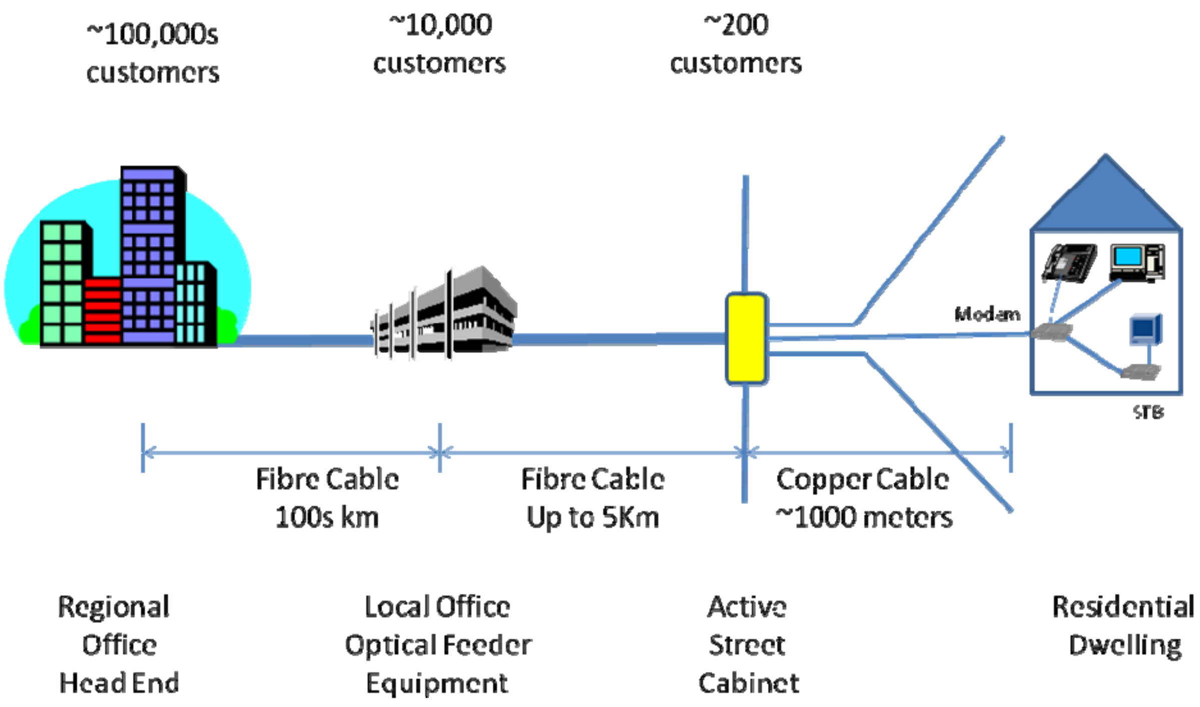

Figure 3: Typical Fibre-to-the-Cabinet architecture.

This architecture can also be referred to as fibre-to-the-cabinet (FTTC) when the opto-electrical conversion is deployed in a street side cabinet, typically serving some 100-600 consumer premises (see Figure 3). In this configuration, the remaining copper cable network will typically have an average length of around

1Km, with 99% of copper pairs less than 2.5Km. It can also be referred to as Fibre-to-the-Kerb (FTTK) where the opto-electrical conversion is deployed in a much smaller street side cabinets, each servicing typically less than 100 consumer premises. In this latter case, the copper cable network typically has an average length of around 300m and 99% of copper pairs are less than 1Km (see Figure 4).

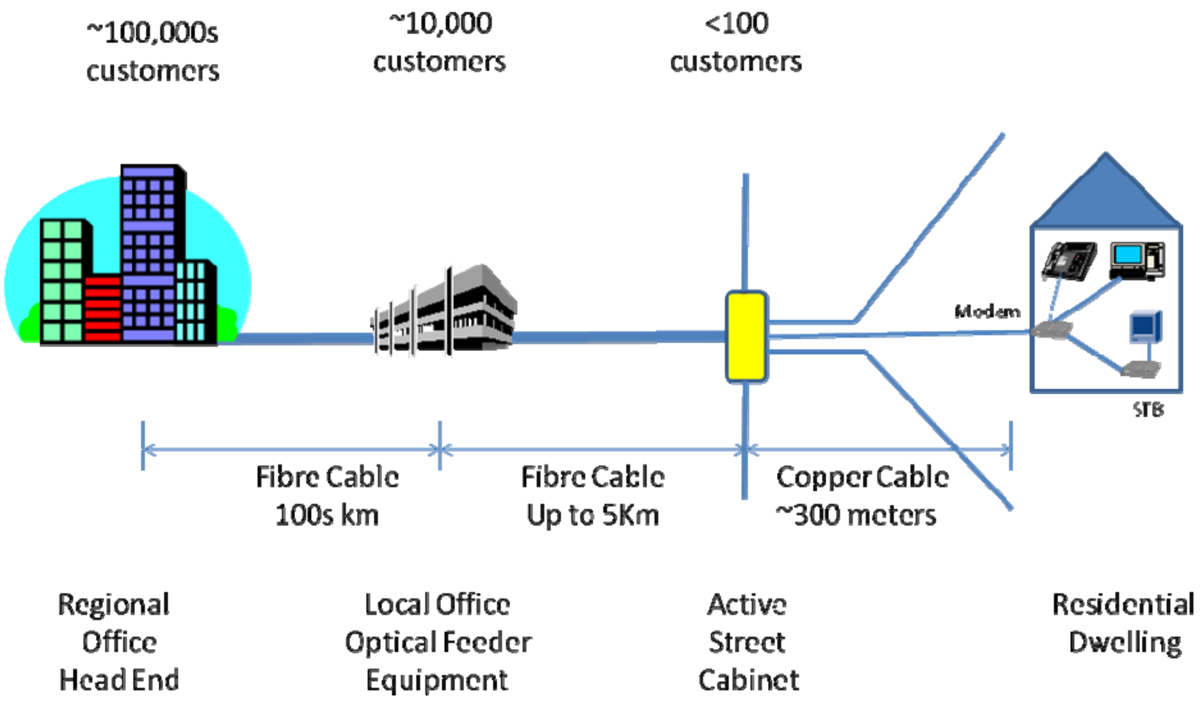

Figure 4: Typical Fibre-to-the-Kerb architecture.

The technology used for the opto-electrical conversion in the street side cabinets is typically based on some form of Digital Subscriber Line (DSL) technology. In the FTTC configuration the most common DSL technology for deployment is ADSL2+ today, although VSDL2 can also be deployed on shorter copper lines. The ADSL2+ technology will achieve downstream line synchronization rates of about 20Mbps on average and better than 10Mbps for better than 99% of access lines. The upstream line synchronization rates will be better than 1.5Mbps on average and better than 1Mbps for more than 99% of access lines. All of these figures, refer to the line termination point on the outside of the consumer premise and may be degraded by in premise wiring and modem characteristics. In the case of FTTK deployments, the most commonly deployed DSL technology is VDSL2, with downstream line synchronization rates of more than 50Mbps and upstream line synchronization rates of more than 10 Mbps.

FTTN is used as a progressive architecture towards FTTP, by an incumbent service provider that has a widely deployed copper cable network already established, and where demand for widespread take-up of high capacity broadband services is uncertain.

In this study the costs of the following FTTP deployments will be analyzed:

- FTTP in the AEF configuration for greenfields,
- FTTP in the AEF configuration for brownfields,
- FTTP in the G-PON configuration for greenfields,
- FTTP in the G-PON configuration for brownfields,

4. Fibre Deployment Costs

Fibre optic cable can be deployed in the access network using a variety of techniques. The most commonly used techniques include:

- Aerial deployment on existing or new poles,
- Shallow trenching,
- Micro trenching,
- Mole plough trenching.
- Directional drilling,
- Open trenching.

The costs associated with each of these deployment techniques is described below. In any given deployment situation, it is highly likely that a combination of some or all of these techniques may be used. Hence the typical deployment cost is a blend of these individual technology costs. The typical blended costs will also be described below.

4.1. Aerial Deployment

Aerial deployment is a low cost approach for the deployment of fibre optic cable where existing poles are available and permission can be obtained to string the cable onto the existing poles. This approach is used widely overseas, where environmental issues involving visual pollution are not a concern. However, in many cities and towns within New Zealand, the issues of visual pollution can be an inhibitor to the use of this approach.

The typical cost for initial deployment on an existing good quality pole infrastructure can be as low as $15-20 per meter. However, it is not usually possible to consistently achieve this low cost for a widespread deployment. It is common to encounter difficulties which add to the deployment costs in a large scale deployment, including:

- The need to replace some poles to handle the increased loading,

- The need to strengthen end poles to handle the increased loading,
- The need to increase pole height and/or tension to enable road crossings,
- The need to provide underground road crossings to meet height restrictions.

When these factors are taken into account, a more typical aerial cost is around $30-50 per meter.

The other factor to consider with aerial deployment is the cost of maintaining the cable over its life cycle. Aerial cable is subject to the following factors:

- Wind loading and fluctuation,
- Pole movement,
- Pole replacement,
- Storm damage.

All of these factors will increase the Total Cost of Ownership (TCO) for aerial cable over its expected lifetime. They may also limit the useful life of an aerial cable system to around 20-30 years, as compared to 40-50 years for a buried system.

Aerial fibre deployment is not possible in any urban areas which already have all underground facilities, so is never going to be universally available as a deployment approach. Many other suburban areas of cities and towns in New Zealand are being targeted for all underground utilities over the next 10-20 years, so again these areas are unsuitable for aerial fibre deployment. Some Local Councils actively discourage the deployment of new aerial plant, so again there will be restrictions on fibre aerial deployment. Some Councils, such as Auckland City Council have been very negative with respect to aerial deployment in the past, but appear to be more receptive today. Hence there is a great deal of variation in the potential for aerial deployment in urban New Zealand. No one has a perfect understanding of what the potential really is and so this represents a large variable in any assessment of costs to deploy FTTP across New Zealand. The best guess would be something in the region of 30-40% of homes and businesses might be suitable for aerial deployment under ideal conditions.

4.2.Shallow Trenching

Shallow trenching is widely used in many countries around the world, but has not been used in New Zealand due to perceived issues with the negative impact of this form of trenching on road maintenance. It involves cutting a trench of about 300mm depth and 100mm width within the surface of a road. There are modern approaches to implementing this technology, which should minimize any impact on road maintenance. These modern techniques involve:

- Specialized deployment machinery,
- Specialized concrete fill materials,

- Specialized resurfacing techniques.

Given all of these techniques, shallow trenching should be able to be deployed in many parts of New Zealand. If this approach can be approved for use by Local Councils, then the cost to deploy fibre should be around $70-90 per meter. This approach should be widely applicable for urban fibre feeder deployment and could also be used for some distribution fibre deployment (although other techniques such as micro trenching could be more applicable for distribution cable).

4.3. Micro Trenching

Micro-trenching involves the cutting of a narrow, shallow trench, typically along the curb of a street. The resulting trench is about 100mm deep and about 15mm wide. A 10mm flexible duct or strip of 2-3 10mm ducts can then be inserted into the trench and then backfilled with concrete emulsion. The micro trenching can also be used to cross footpaths in order to provide entry into premises and can be deployed alongside grass verges for both transverse and premise entry situations.

The cost for the micro trenching varies considerably depending on the situation within which it is deployed. Along street curbs it can be in the range of $50-70 per meter. Alongside grass verges and for premise lead-ins it can be as low as $30-50 per meter.

Micro trenching should only be used in the distribution and premise lead-in parts of the access network. For these applications, it is the most cost effective deployment approach where burial is required. It should not be deployed in the feeder parts of the network as the potential for damage is higher than that for other burial techniques. It should only be used at the extremities of the network where a cable cut will only impact a relative small number (less than 100) of customers.

Currently Local Councils in New Zealand universally prohibit the use of micro trenching. However, their logic for this prohibition is not clear. Properly deployed, micro trenching does not present a maintenance risk for either roads or footpaths. As mentioned above, due to the shallow depth of cable burial, the greatest risk is to the cable itself due to normal road work activities. Certainly, there will need to be increased care in undertaking road maintenance, but this is not considered to be a major problem in overseas jurisdictions where this technology is deployed in a well defined and best practice manner.

Certainly, other than aerial deployment, this is the most promising approach to achieve reduced costs for fibre deployment to homes in New Zealand. Any other burial approach will add some 30-50% additional cost to the deployment per home connected. Hence it is essential to achieve acceptance of this technique as part of any widespread deployment of FTTP in New Zealand. One approach to achieve this goal would be for the Government to fund a properly managed micro-trenching pilot with all interested local authorities involved. The pilot could be thoroughly examined for short and long term impacts on road and footpath maintenance and specific best practice deployment standards could be defined for consistent application throughout New Zealand.

4.4.Mole Plough Trenching

Mole plough trenching involves the use of a mechanized digger which digs a 600-1200mm deep trench about 200mm wide into which duct can be laid, then back filled in a continuous run, typically all in one largely mechanized operation. Unfortunately, a mole plough can only operate in soft ground such as topsoil and loosely compacted clay. Hence it is widely used for deployment of fibre in rural areas, but can seldom be used to deploy in urban areas.

The cost for deployment of fibre using a mole plough varies depending on the ground conditions, but typically lies in the range of $20-40 per meter. However, as indicated above, the amount of mole plough trenching that could be used in an urban FTTP deployment would be very small – less than 5%. On the other hand, if fibre deployment in rural New Zealand is contemplated, this could be a very useful deployment approach.

4.5.Directional Drilling

Directional drilling involves the use of a horizontal drilling machine which drills an up to 100mm diameter hole horizontally along the ground at a depth of around 0.8 to 1.2m. The drill can operate over a horizontal run of up to about 100-200m, depending on ground conditions. At each end of the run, a hole must be dug to enable the laying of a continuous run of 50-100mm duct. The fibre cable is then typically blown through sub-ducts or tubes contained within the outer duct.

Directional drilling has a high capital cost for the drilling machinery and a lower operational cost, so is suited to wide-scale deployments. It operates best in softer soil substrates such as clay and loosely compacted rock. It does not function in solid rock substrates or in substrates which contain sizeable boulders. Even relatively small stones within the substrate such as found in shingle can be troublesome – putting the drilling head off course very rapidly and repeatedly. Even small amounts of solid matter can be troublesome in areas containing many other underground services such as water, sewage, power and gas. Any mis-placement of the drilling head can lead to serious and costly disruption to other services.

The cost for directional drilling is again highly variable, depending on ground conditions. It is widely used in some cities such as Christchurch and Hamilton, but can be very challenging in cities such as Wellington, Dunedin and parts of Auckland.

The typical cost for directional drilling when it can be used is around $50-70 per meter. Directional drilling typically needs to be combined with traditional open trenching (see below). A typical deployment would involve 80% drilling and 20% open trenching, so that the weighted cost per meter is more normally around $70-90 per meter in suburban areas and $100-120 per meter in Central Business Districts. These figures of course can vary considerably due to local ground conditions and the technique is certainly not applicable to more than about 50-60% of urban New Zealand.

Ericsson have recently demonstrated the use of a new directional drilling approach, which employs substantially more sophisticated technology than that for the more traditional directional drilling approach. They call it an Intelligent Directional Drilling system, which includes:

- A guided directional drill of new design,
- Ground penetrating radar to accurately locate existing services,
- A mobile vacuum unit to water blast holes and such out the waste material,
- A new system of blown fibre.

The drilling approach is claimed to enable directional drilling along one side of the road for the fixed passive component of the installation, with the connections being made under the road. The use of a single sided deployment (see below) could significantly reduce the fixed passive component of the costs and it is claimed that the variable premise connection can also be reduced relative to traditional approaches. Currently there is insufficient data on this technology to apply it to the models. However, it is recommended that it be investigated further to both understand the conditions under which it can be used and the resulting cost structure.

4.6. Open Trenching

Open Trenching is the traditional and last resort approach to burial of fibre optic cable in urban situations. The burial involves the digging of a 200-300mm wide trench using a back hoe or digger. The depth of the trench is typically 0.8 to 1.2m deep. The 50-100mm duct (and potentially multiple ducts) is laid in the trench and the trench is back filled (often with new hard core) and compacted to normal ground level. This is a highly labor intensive process and so the costs are high.

Open Trenching costs depend greatly on local ground conditions and local Council requirements for compacting and surface reinstatement. When a trench is dug into a road surface, the re-instatement requirements can be considerable and highly expensive. Simple trenching can cost as little as $120-150 per meter. However, when substantial concrete cutting, rock cutting and reinstatement is required the costs can explode to $500-600 per meter. Many budgets have been blown out due to encountering unexpected conditions while undertaking open trenching. Obviously, for these reasons, open trenching is used as a last resort in any urban fibre deployment, but is often necessary in some locations, such as where manholes must be deployed.

4.7.Actual FTTP Deployment Costs

As can be seen from the above descriptions of individual deployment approaches, costs can vary considerably. The variability will arise from many factors including:

- Type of terrain (flat or hilly)
- Type of ground (soil, clay or rock)
- Type of deployment (greenfields vs brownfields),
- Availability of poles,
- Single sided verses double sided deployment,
- Local Council constraints,
- Dwelling density,
- Type of architecture,
- Cost of labour,
- Availability of suitable machinery,
- Cost of reinstatement materials,

Given all of these factors there can be no single cost for deployment of FTTP. However, given all these factors, one can provide some indicative ranges for large scale deployment, in the thousand kilometer range. The typical ranges would be as follows:

- If the area to be covered has an available pole infrastructure which can be accessed, one would expect a deployment cost in the range of $30-50 per meter,
- If the area to be covered requires largely burial and newer trenching techniques, such as shallow and micro trenching can be used, then the deployment cost would be expected to be in the range of $50-70 per meter,
- If the area to be covered requires largely burial and only traditional burial techniques such as directional drilling and open trenching can be used, then the deployment cost would be expected in the range of $70-90 per meter,
- If the area to be covered requires largely burial and only open trenching is possible due to ground conditions and regulatory constraints, then the deployment cost would be expected to be in the range of $100-200 per meter and possibly higher.

Given these typical cost ranges for the various deployment technologies, the other primary factor affecting deployment cost is the deployment architecture. The traditional approach to buried deployment has been to bury the duct down each side of the street, with connections to premises typically at the boundaries of two adjacent premises. This burial approach has been essential with most of the currently available technologies as any disruption to a road surface or substrate has always been a very expensive component of the deployment due to:

- The cost associated with any form of surface restoration,
- The difficulty of avoiding all of the other services lying within the road corridor.
- Both of the above resulting in difficult permit requirements with Local Councils.

This double sided deployment approach affectively doubles the length of the trenching required relative to the length of road being traversed.

On the other hand, aerial deployment can be undertaken on a single sided basis in some locations and this approach is taken in many parts of New Zealand today where telecommunication services are delivered via overhead plant. It is not universal however as the road crossings required to make connections into premises must be done at a minimum height which is often not available when telecommunications plant is located below electricity plant on the same poles. This limitation can drive the need for two sided deployment or expensive road crossings.

In the models which follow, double sided deployment is used throughout in order to simplify the models. It is acknowledged that this could penalize the aerial deployment areas. It would also penalize any areas which might be implemented using the new Ericsson Intelligent Directional Drilling approach (this approach has not been included in the modeling to date). However, as the proportion of these deployment approaches used in the current models is relatively low, it is considered that the lowest unit cost bound probably encompasses this variation reasonably well. A more sophisticated modeling approach (such as the block based approach recommended for future work) would be needed to properly incorporate the areas which can be deployed on a single sided basis. It should also be noted that the customer lead-in would increase in length relative to that used in the current models under a single sided deployment approach. This would require another adjustment to the models.

5. Geographical Coverage

The National Party proposal was to provide FTTP to 75% of the population of New Zealand. In the 2006 Department of Statistics census figures for New Zealand there were 1,454,175 residential premises in New Zealand. Of these approximately 1.1 million are classified as urban dwellings. Scattered in amongst these residential premises though, there are also a large number of small to medium business premises, typically with less than 100 employees per premise. Most have 5 or less employees. Within the 75% of most densely populated areas of New Zealand, the residential dwellings and business premises covered is estimated to be as follows:

- Residential dwellings: 1.1 million
- Business premises: 0.34 million

These figures will be used for the analysis that follows.

6. Passive FTTP Deployment Costs

6.1.Passive Optical Networking

Azimuth Consulting have recently undertaken a study on the passive deployment costs for FTTH, based on a couple of actual suburban studies[1]. This work was undertaken for the Ministry of Economic Development. A companion study on active costs was also prepared for the Ministry of Economic Development by Milner Consulting Limited[2]. The results from this paper will be discussed in the next section.

The passive cost analysis prepared by Azimuth assumes the following:

- The use of a G-PON architecture into suburban residential areas,
- The use of zero existing duct infrastructure,
- The use of buried plant, using a combination of directional drilling and open trenching,
- The use of blown fibre technology in buried micro-ducts,
- A feeder distance to the residential area of 800m,
- A distribution network per household passed of 16m, based on a double sided deployment,
- An average customer lead-in length of 15m.

The cost model does not include the following cost elements:

- Regional backhaul network(s),
- Equipment accommodation costs,
- Operating and maintenance costs,
- Territorial local authority rates.

[1] Azimuth Consulting, Fibre-to-the-Home Passive Component Costs, 14 November 2008.
[2] Milner Consulting Limited, Fibre-to-the-Home Active Component Costs, 19 November 2008.

Based on the above assumptions, the average cost of deployment for the distribution fibre plant is $72.50 per meter. The fixed cost per residential premise passed is estimated to be $1,760 and the variable cost per customer connection is estimated to be $946.

If this model is to be extrapolated to cover the 75% of dwellings proposed for urban New Zealand, it is necessary to assume some distribution of conditions likely to be encountered across this scale of deployment. A simplistic approach would take the existing model and assume it can be deployed across New Zealand. With a population of residential homes amounting to some 1.1 million and business premises amounting to some 0.34 million, this would suggest a total passive fixed cost for deployment of $2.552B.

Unfortunately this simplistic approach does not properly reflect the realities of deploying a fibre network across urban New Zealand. Within the defined coverage area, there are widespread variations in both premise densities and deployment conditions. Hence in any realistic model we need to address these issues in a more thorough manner. The two key areas of major variation relate to:

- The length of the premise frontage,
- The cost per meter for deployment.

These two issues are discussed in detail below.

The length of premise frontage is dependent on two key factors:

- Population density,
- Mix of business and residential premises.

The density of population across the 75% of urban New Zealand as required for this analysis varies considerably, but it is widely recognized that for residential situations, the weighted average frontage sits somewhere between 16 and 18m, and that 17m is a best estimate. The situation with respect to business premises scattered throughout urban New Zealand however, is by no means as clear-cut. Depending on the type of business, the frontage can vary from 10m to well over 100m. A school for example will typically have a frontage of over 100m, while a corner diary will be down in the 10-20m region. A likely model for businesses scattered within urban New Zealand will be as follows:

- 10% of premises have a frontage of around 100m,
- 10% of premises have a frontage of between 50 and 100m,
- 20% of premises have a frontage of between 30 and 50m,
- 30% of premises have a frontage between 20 and 30m,
- 30% of premises have a frontage between 10 and 20m.

Taking the midpoint of these ranges and performing a weighted average, we find that the typical business frontage is estimated to be 37.5m. When this figure is weighted on a proportion of premises basis with that for residential, the likely weighted average length of frontage across urban New Zealand is about 21.9m. Unfortunately, there is a lot of uncertainty in this number, so it is wise to provide some sensitivity analysis. A top down analysis of the length of urban roads to cover 75% of premises shows that the single sided deployment would be in the range of about 10m. Based on these two estimation approaches, it is proposed that the actual weighted average length of frontage will lie in the range of 18 to 22m and so calculations will be done at 18, 20 and 22m to show the sensitivity to this potential uncertainty.

In a similar manner we can develop a model to account for the potential variation in deployment costs. A likely model for the distribution of deployment costs is as follows:

- 30% aerial deployment at $40 per meter,
- 30% low cost burial deployment at $60 per meter,
- 30% standard burial deployment at $80 per meter,
- 10% open trenching deployment at $150 per meter.

The weighted average of these costs is $69 per meter. This can be considered to be a likely deployment cost for urban New Zealand, but the actual value could still vary considerably from this value, due to the various assumptions that have been made in this model. In order to illustrate the sensitivity to deployment cost the analysis is undertaken at deployment costs of 50, 70 and 90 dollars per meter.

When these figures are inserted into the Azimuth passive cost model, the average passive fixed cost per premise passed is as illustrated in Table 1 below. The figure varies from $1487 to $2621 per premise passed, depending on the deployment assumptions used. The most likely figure will be around $2012, when averaged across all conditions likely to be encountered throughout urban New Zealand.

	$50 per meter	**$70 per meter**	**$90 per meter**
18 m Frontage	$1,487	$1,865	$2,243
20 m Frontage	$1,592	**$2,012**	$2,432
22 m Frontage	$1,697	$2,159	$2,621

Table 1: Passive fixed costs per premise for PON based FTTP deployment across urban premises in New Zealand.

Applying the figures contained in Table 1 to the entire urban distribution of residential and business premises, the best estimate for the likely deployment investment for the passive infrastructure only is shown in Table 2.

	$50 per meter	$70 per meter	$90 per meter
18m Frontage	$2,141	$2,685	$3,230
20m Frontage	$2,292	**$2,897**	$3,502
22 m Frontage	$2,443	$3,109	$3,774

Table 2: Passive fixed investment for deployment of PON based FTTP to the 75% of urban premises in New Zealand.

It is clear from this analysis that the overall cost for passive deployment can vary considerably, depending on the conditions encountered across the target population. Overall, it can be expected that even with the lowest cost deployment approaches being used, where-ever possible, there is a better than 95% probability that the fixed cost to deploy FTTP to 75% coverage of urban New Zealand will be more than $2.1B. There is also better than 95% probability that the fixed cost to deploy FTTP to 75% coverage of New Zealand will be less than $3.8B. It is most likely that the fixed cost for passive infrastructure will lie in the range of $2.6B to $3.3B.

The variable costs to deploy the passive components of FTTP will also be subject to considerable variation. Again in order to take this variation into account, the cost per meter of deployment has been assumed to lie within the range of $20 to $40 and a sensitivity analysis has been undertaken at $20, $30 and $40 per meter. Similarly, the length of the premise entry varies considerably and is assumed to lie within the range of 15 to 19m and so sensitivity analysis has been undertaken at 15, 17 and 19m. Based on these parameters, the variable passive cost per premise has been derived based on the Azimuth model and is summarized in Table 3 below. The variable unit cost lies in the range from $796 to $1256 with the most likely unit cost being about $1006. It must be emphasized that in this model the lead-in includes both the on premise component, plus the length of blown fibre optic cable back to the first optical splitter. This is considered to be the most cost effective deployment approach given the uncertainty of the expected market take-up.

	$20 per meter	$30 per meter	$40 per meter
15m Lead-in	$796	$946	$1,096
17m Lead-in	$836	**$1,006**	$1,176
19m Lead-in	$876	$1,066	$1,256

Table 3: Variable passive costs per premise for G-PON deployment in urban New Zealand.

Given both the fixed and the variable unit cost figures, an estimate of the total cost for connecting a given premise can be made. This involves assuming some form of take-up rate for the fibre based services. Figures are provided at 25%, 50%, 75% and 100% take-up in order to show the likely range of unit costs involved depending on take-up rate. These unit costs are shown in Table 4 below.

100% Take-up (NZD)			
100%	**$20 per meter**	**$30 per meter**	**$40 per meter**
15m Lead-in	$2,955	$3,105	$3,255
17m Lead-in	$2,995	$3,165	$3,335
19m Lead-in	$3,035	$3,225	$3,415
75% Take-up (NZD)			
75%	**$20 per meter**	**$30 per meter**	**$40 per meter**
15m Lead-in	$3,675	$3,825	$3,975
17m Lead-in	$3,715	$3,885	$4,055
19m Lead-in	$3,755	$3,945	$4,135
50% Take-up (NZD)			
50%	**$20 per meter**	**$30 per meter**	**$40 per meter**
15m Lead-in	$5,114	$5,264	$5,414
17m Lead-in	$5,154	$5,324	$5,494
19m Lead-in	$5,194	$5,384	$5,574
25% Take-up (NZD)			
25%	**$20 per meter**	**$30 per meter**	**$40 per meter**
15m Lead-in	$9,431	$9,581	$9,731
17m Lead-in	$9,471	$9,641	$9,811
19m Lead-in	$9,511	$9,701	$9,891

Table 4: Passive cost per premise connected for urban G-PON deployment in New Zealand.

The 100% take-up figures are those which are most often quoted in the literature, as these make the costs look to be most attractive. These sit in the range from about $2950 to $3400 per home connected. This range assumes that the fixed passive cost per premise passed lies in the midrange of that estimated in Table 1 above. The important feature to note from Table 4 is that for low take-up of fibre based service, the passive cost per premise connected increases dramatically. With only 25% take-up the cost could be as much as $10,000 per premise connected. This shows that in order for a fibre based infrastructure to be economical, it is essential that there is a very high penetration of users. This is the basis for the argument for Government to subsidize such a rollout, as the demand risk over the first 5-10 years is too high for a typical publicly listed company to contemplate.

6.2. Active Ethernet Fibre Passive Costs

The fixed passive AEF costs are similar to those for the PON scenario. The feeder costs increase substantially, due to the dramatically increased fibre count, but this does not impact on the overall cost per home passed substantially. Using the same assumptions as those for the G-PON cost model described above, the best estimate for the passive fixed cost per home passed is shown in Table 5.

	$50 per meter	**$70 per meter**	**$90 per meter**
18m Frontage	$1,593	$1,971	$2,349
20m Frontage	$1,698	$2,118	$2,538
22m Frontage	$1,803	$2,265	$2,727

Table 5: Fixed passive cost per premise passed for the deployment of AEF across urban New Zealand.

The range is now from $1600 to $2700 per premise passed. At the medium cost, the increase in cost per home passed relative to that for G-PON is about 5%. This is due to the low cost today of fibre cable – the bulk of the cost is involved in digging the hole or stringing the cable and so the increase in the cost of the cable is marginal over the deployment which is common to both approaches.

It should be noted though that there is one issue that the current models don't highlight well. The costs for the feeder assume the use of the distribution trench. This would be valid for most deployment approaches. However, if micro trenching is used on a wide-scale basis, there will be some constraints on the capacity of the distribution trench to accommodate the much larger feeder cables in the AEF case. Hence there may need to be specific allowance made for the trenching associated with the feeder cable in the AEF case which is not required for the G-PON feeder case. This may drive additional cost into the AEF case as compared to the G-PON case, which has not been included in the current models.

The variable passive costs for AEF are identical to those for the G-PON case. Again, it is assumed that the distribution cable is only blown out to the last street pillar or enclosure until a customer requests service. Then the lead-in cable is blown through the existing duct to the premise and the lead-in cable is spliced into the passing duct. It should also be emphasized that this model assumes a double sided street deployment for the distribution. This is correct for comparison purposes with the G-PON case, but it is accepted that both cases may be able to have reduced costs if more single sided deployment is possible. This is yet to be proven, so is not included in either of these models to date.

7. Active FTTP Deployment Costs

7.1. Service Model

In order to define the active costs associated with any form of fibre based access deployment, it is necessary to assume a specific service model. The service model used for all of the scenarios considered in this report is as follows:

- The baseline service set delivered over the fibre based infrastructure in all cases is Primary Line Voice (PLV) combined with High Speed Internet (HIS),
- The enhanced service set involves the provision of the above, plus the provision of a video service – this might include PayTV, VoD, or any combination thereof.

In the models which follow, it is assumed that all customers take the baseline service set and some customers (less than 50%) take the enhanced service set. It is also assumed that any form of Optical Network Terminal located on the customer premise is capable of supporting the baseline and enhanced service sets, so that future upgrades can be achieved without change to these devices.

There are also a number of service options which have been considered. The main option reflected into the models is the choice of the customer to include backup battery power for the ONT. This capability is required to support a lifeline based PLV. The terminal equipment supplied is capable of supporting this option, but it is the customer's choice as to whether it is installed and hence the cost is incurred. Again the actual take-up of this capability is unknown. Hence it is again assumed that around 50% of all customers take-up this option.

7.2. Passive Optical Networking

The active deployment costs have been studied by Milner Consulting Limited in a paper prepared for the Ministry of Economic Development as mentioned above. These costs are also highly variable depending on the level of functionality, the take-up of services and the timeframe used for the assessment. The summary picture is illustrated in Table 6.

Probability	2006	2008	2010	Weighting
Low	$995	$796	$647	10%
Medium	$1,276	$1,021	$841	20%
High	$1,901	$1,521	$1,216	40%

Medium	$3,162	$2,380	$1,897	20%
Low	$3,625	$2,750	$2,175	10%
Weighted Av.	**$2,110**	**$1,643**	**$1,316**	

Table 6: Weighted average cost per premise connected for the active components in a G-PON deployment for urban New Zealand.

As can be seen from the table there is no single cost for the active components for a G-PON deployment. The costs will vary greatly depending on the mix of factors encountered in association with a specific deployment. At a minimum, the active cost per home connected could be as little as NZD796 or as much as NZD2750 in 2008 (with exchange rates as at 1 November 2008). The outstanding question will be the probability of these values occurring in practice. In the analysis presented in Table 6, probabilities have been attached to each of the possible outcomes, and the results have been analyzed on a statistical basis to determine the probability of a given cost occurring. The allocation of probabilities is not highly scientific as there is no proven basis for this type of statistical analysis. Instead it is based on historical experience associated with the likely take-up of various technologies in a relatively new market. This in itself is multi-dimensional as there are various types of take-up involved in this analysis, including:

- Take-up related to the basic technology and the associated timeframe for this to occur,
- Take-up related to the services (telephony, fast Internet and video) which can be delivered over the basic technology,
- Take-up of additional functionality, such as backup power and advanced STB features,
- Take-up within premises with different cabling requirements.

The probability analysis has attempted to take all these factors into account in a rational manner. Based on this somewhat subjective statistical analysis the weighted average results shown in table 6 have been calculated. As can be seen this value was about NZD2110 in 2006 and is expected to fall to about NZD1320 in 2010, with current costs sitting at NZD1650. It will be noted that the weighted average is higher than the median figures in the table as the costs for a Set Top Box, Backup Power and complexity of cabling, skew the distribution towards the higher values. On the other hand, if consumers select more of the lower functional components, then the cost will be skewed towards the lower end of the range.

In order to provide a complete picture of the G-PON costs per home connected, the information contained in Table 6 has been rearranged to provide high, medium and low cost bounds based on the 2008 data. These scenarios are presented in Table 7 relative to take-up of service and include a breakdown in terms of the costs most likely to be allocated to the service provider and those most likely to be allocated to the consumer. The take-up figures in this analysis relate to the take-up per Central Office site and typically relate to the fixed costs verses the variable costs on a per CO site basis. 100% take-up represents an optimal allocation of fixed and variable costs, while the other figures represent less optimal cases. On a CO basis, it would be unusual to achieve better than about 80% utilization of the variable cost plant located at a single site. On the other hand, there would be a low likelihood of deploying a solution at a Central Office, if the utilization was to be less than 25%.

As can be seen from Table 7, the cost of the common equipment in the G-PON architecture is very low and the bulk of the service provider costs lie in the ONT. Note that this statement assumes a high take-up of service within the given Central Office serving area. When the uptake is low, the network costs do start to have a significant impact on the overall active cost component.

For a basic consumer configuration, not involving video services, the bulk of the consumer costs lie in the re-cabling of the premise to accommodate the new telephony and broadband connections, terminating at the ONT. As additional devices are included to accommodate video services and battery back-up for the ONT, so both the service provider and consumer costs increase.

Low Cost Scenario				
2008 Cost Estimates	**100% Uptake**	**75% Uptake**	**50% Uptake**	**25% Uptake**
Common Network Equipment	$26	$46	$104	$417
Optical Splitter	$70	$93	$140	$280
Optical Network Terminal	$417	$417	$417	$417
Set Top Box	$0	$0	$0	$0
In-premise Cabling	$333	$333	$333	$333
Total Cost	$846	$890	$994	$1,447
Service Provider Cost	$513	$556	$661	$1,113
Consumer Cost	$333	$333	$333	$333
Medium Cost Scenario				
2008 Cost Estimates				
Common Network Equipment	$26	$46	$104	$417
Optical Splitter	$70	$93	$140	$280
Optical Network Terminal	$583	$583	$583	$583
Set Top Box	$333	$333	$333	$333
In-premise Cabling	$500	$500	$500	$500

Total Cost	$1,513	$1,556	$1,661	$2,113
Service Provider Cost	$679	$723	$828	$1,280
Consumer Cost	$833	$833	$833	$833
High Cost Scenario				
2008 Cost Estimates				
Common Network Equipment	$26	$46	$104	$417
Optical Splitter	$70	$93	$140	$280
Optical Network Terminal	$833	$833	$833	$833
Set Top Box	$750	$750	$750	$750
In-premise Cabling	$750	$750	$750	$750
Total Cost	$2,429	$2,473	$2,578	$3,030
Service Provider Cost	$929	$973	$1,078	$1,530
Consumer Cost	$1,500	$1,500	$1,500	$1,500

Table 7: Variable active costs per premise connected for a G-PON deployment across urban New Zealand.

The biggest determining factor in these costs is the provision of video services over the fibre infrastructure. However, from a revenue and demand perspective video services are likely to be very important and they also provide means to cover the high fixed costs associated with the new passive infrastructure.

7.3.Active Ethernet Fibre

The active costs for AEF are derived in a similar manner to that for G-PON, except that there is no splitter component and there is an optical port per premise. This latter factor is the most significant difference between the AEF and G-PON unit costs. The weighted average cost summary is shown in Table 8.

Probability	**2006**	**2008**	**2010**	**Weighting**
Low	$1,875	$1,500	$1,225	10%
Medium	$2,500	$2,000	$1,625	20%
High	$3,333	$2,667	$2,158	40%
Medium	$4,458	$3,417	$2,800	20%
Low	$6,125	$4,750	$3,800	10%
Weighted Av.	**$3,525**	**$2,775**	**$2,251**	

Figure 8: Weighted average variable active costs per premise connected for AEF deployment across urban New Zealand.

As can be seen by comparing the costs in Table 6 with those in Table 8, the unit costs are considerably higher, driven by the common network equipment costs. Based on the 2008 figures the cost penalty from using AEF is estimated to be close to 100%.

Table 9 shows the low, medium and high cost scenarios for the active costs per premise connected. The trends are very similar to those for the G-PON case, except that the Common Network Equipment costs are substantially higher. This outcome should not be surprising as the AEF architecture requires an optical port per consumer at the Central Office, while the G-PON architecture only requires one port per about 50 customers. Even though the G-PON optical port is some 3 times more expensive than the AEF port, the cost difference will still be around an order of magnitude as shown by the comparison of Tables 7 and 9.

Low Cost Scenario				
2008 Cost Estimates	**100% Uptake**	**75% Uptake**	**50% Uptake**	**25% Uptake**
Common Network Equipment	$500	$667	$1,000	$2,000
Optical Splitter	$0	$0	$0	$0
Optical Network Terminal	$500	$500	$500	$500
Set Top Box	$0	$0	$0	$0
In-premise Cabling	$333	$333	$333	$333
Total Cost	$1,333	$1,500	$1,833	$2,833
Service Provider Cost	$1,000	$1,167	$1,500	$2,500
Consumer Cost	$333	$333	$333	$333
Medium Cost Scenario				
2008 Cost Estimates				
Common Network Equipment	$500	$667	$1,000	$2,000
Optical Splitter	$0	$0	$0	$0
Optical Network Terminal	$833	$833	$833	$833
Set Top Box	$333	$333	$333	$333
In-premise Cabling	$500	$500	$500	$500
Total Cost	$2,167	$2,333	$2,667	$3,667
Service Provider Cost	$1,333	$1,500	$1,833	$2,833
Consumer Cost	$833	$833	$833	$833
High Cost Scenario				

2008 Cost Estimates				
Common Network Equipment	$500	$667	$1,000	$2,000
Optical Splitter	$0	$0	$0	$0
Optical Network Terminal	$1,250	$1,250	$1,250	$1,250
Set Top Box	$750	$750	$750	$750
In-premise Cabling	$750	$750	$750	$750
Total Cost	$3,250	$3,417	$3,750	$4,750
Service Provider Cost	$1,750	$1,917	$2,250	$3,250
Consumer Cost	$1,500	$1,500	$1,500	$1,500

Table 9: Active cost per premise connected for three cost scenarios for AEF deployment across urban New Zealand.

8. Total FTTP Deployment Costs

8.1. Total PON Deployment Costs

When the entire deployment cost analysis is brought together, we end up with the unit cost picture as illustrated in Table 10 for a G-PON deployment. This table shows the total cost per premise connected under the various take-up and cost scenarios. As can be seen from the table, under the 100% take-up scenario the total cost per premise connected varies over the range from $3129 to $6306. These figures emphasize the importance of achieving the lowest possible deployment cost for the passive infrastructure. Keeping the service provider component of the costs down is also important, especially that related to the ONT.

100% Uptake	75% Uptake	50% Uptake	25% Uptake
$1,487	$1,982	$2,974	$5,947
$796	$796	$796	$796
$846	$890	$994	$1,447
$513	$556	$661	$1,113
$333	$333	$333	$333
$3,129	**$3,668**	**$4,764**	**$8,190**
$2,796	$3,335	$4,431	$7,857
$333	$333	$333	$333
100% Uptake	**75% Uptake**	**50% Uptake**	**25% Uptake**
$2,012	$2,682	$4,024	$8,047

$1,006	$1,006	$1,006	$1,006
$1,513	$1,556	$1,661	$2,113
$513	$723	$828	$1,280
$833	$833	$833	$833
$4,531	**$5,245**	**$6,691**	**$11,167**
$3,531	$4,411	$5,857	$10,333
$833	$833	$833	$833
100% Uptake	**75% Uptake**	**50% Uptake**	**25% Uptake**
$2,621	$3,494	$5,242	$10,483
$1,256	$1,256	$1,256	$1,256
$2,429	$2,473	$2,578	$3,030
$929	$973	$1,078	$1,530
$1,500	$1,500	$1,500	$1,500
$6,306	**$7,223**	**$9,075**	**$14,769**
$4,806	$5,723	$7,575	$13,269
$1,500	$1,500	$1,500	$1,500

Table 10: Total cost per connection for G-PON deployment across urban New Zealand.

This issue is further highlighted when we look at the cost per premise connected with 25% take up of service. Under these conditions, the fixed costs really dominate with the cost per premise connected lying in the range from $8190 to just under $15000. It would be extremely hard to ever achieve a return on investment with this type of cost structure. Even with 50% take up of service, the costs per connection are high making achieving a return on investment challenging. It is obvious from these figures that the take-up on G-PON infrastructure needs to be in the 75% range or better to get the unit costs into a useful range. The return on investment will then be determined by the services supported and the time it takes to achieve this level of penetration.

8.2. Total Active Ethernet over Fibre

The total cost of providing AEF consists of the sum of the passive and active components, subject to the take-up of service. As for the PON case, the active and passive components are combined as in relation to the take-up of the broadband services over the fibre infrastructure.

100% Uptake	75% Uptake	50% Uptake	25% Uptake

$1,593	$2,124	$3,186	$6,373
$796	$796	$796	$796
$1,333	$1,500	$1,833	$2,833
$1,000	$1,167	$1,500	$2,500
$333	$333	$333	$333
$3,723	**$4,420**	**$5,816**	**$10,002**
$3,389	$4,087	$5,482	$9,669
$333	$333	$333	$333
100% Uptake	**75% Uptake**	**50% Uptake**	**25% Uptake**
$2,118	$2,824	$4,236	$8,473
$1,006	$1,006	$1,006	$1,006
$2,167	$2,333	$2,667	$3,667
$1,333	$1,500	$1,833	$2,833
$833	$833	$833	$833
$5,291	**$6,164**	**$7,909**	**$13,145**
$4,458	$5,330	$7,076	$12,312
$833	$833	$833	$833
100% Uptake	**75% Uptake**	**50% Uptake**	**25% Uptake**
$2,727	$3,636	$5,454	$10,909
$1,256	$1,256	$1,256	$1,256
$3,250	$3,417	$3,750	$4,750
$1,750	$1,917	$2,250	$3,250
$1,500	$1,500	$1,500	$1,500
$7,233	**$8,309**	**$10,460**	**$16,915**
$5,733	$6,809	$8,960	$15,415
$1,500	$1,500	$1,500	$1,500

Table 11: *Total cost per connection for AEF deployment across urban New Zealand.*

The trends for the AEF deployment are similar to those for the PON deployment, except that the absolute cost per connected premise is higher in all scenarios by about 13 to 18%. Hence it does appear that in line with other analysis, the cost penalty for the use of AEF technology over PON is about 15% on average.

In a realistic deployment scenario, it is most likely that a combination of both technologies would be used, with AEF being implemented for primarily business consumers and residential consumers located in multi-tenant buildings and campuses, while G-PON technology would be used to provide services to suburban residences. As this unit cost difference is largely driven by active costs, this differential is likely to change over time with the AEF costs slowly closing some of the gap with PON costs. However, the prime difference between the two architectures will always remain so that some cost penalty in the use of AEF could be expected to be persistent. On the other hand, the benefits of using the AEF approach from a customer demand perspective could outweigh this cost difference over time.

9. Investment Summary

The above analysis is presented in the form of unit costs per premise passed and connected. In this section we investigate the investment required to deploy these PON and AEF technologies across the 75% of urban New Zealand as proposed by the National Party. As discussed in section 5 above, this represents some 1.44 million premises, including a mix of both residential and business premises.

9.1. Total Investment for G-PON Deployment

If G-PON was to be deployed such that it passed all 1.44 million premises and all 100% of these premises were to be connected and provided with service, then the likely cost for such a deployment would be represented by the figures contained in column 2 of Table 12. The other columns show the change in investment required when all premises are passed but the take-up of service is reduced from 100% down to 25%.

As can be seen from the table, the total investment required varies from a maximum of about $9.1B with 100% take-up down to a minimum of about $2.9B with 25% take up. The potential investment figures vary over a 3:1 range, which illustrates the difficulty with providing a single number for the investment required to deploy FTTP in New Zealand.

Low Cost Scenario				
Uptake	**100%**	**75%**	**50%**	**25%**
Passive Fixed Cost	$2,141	$2,141	$2,141	$2,141
Passive Variable Cost	$1,146	$860	$573	$287
Active Variable Cost	$1,218	$961	$716	$521
Service Provider Cost	$738	$601	$476	$401
Consumer Cost	$480	$360	$240	$120
Total Cost (NZD Millions)	**$4,506**	**$3,962**	**$3,430**	**$2,948**

Service Provider Cost	$4,026	$3,602	$3,190	$2,828
Consumer Cost	$480	$360	$240	$120
Medium Cost Scenario				
Uptake	**100%**	**75%**	**50%**	**25%**
Passive Fixed Cost	$2,897	$2,897	$2,897	$2,897
Passive Variable Cost	$1,449	$1,087	$724	$362
Active Variable Cost	$2,178	$1,681	$1,196	$761
Service Provider Cost	$738	$781	$596	$461
Consumer Cost	$1,200	$900	$600	$300
Total Cost (NZD Millions)	**$6,524**	**$5,664**	**$4,817**	**$4,020**
Service Provider Cost	$5,084	$4,764	$4,217	$3,720
Consumer Cost	$1,200	$900	$600	$300
High Cost Scenario				
Uptake	**100%**	**75%**	**50%**	**25%**
Passive Fixed Cost	$3,774	$3,774	$3,774	$3,774
Passive Variable Cost	$1,809	$1,357	$904	$452
Active Variable Cost	$3,498	$2,671	$1,856	$1,091
Service Provider Cost	$1,338	$1,051	$776	$551
Consumer Cost	$2,160	$1,620	$1,080	$540
Total Cost (NZD Miliions)	**$9,081**	**$7,801**	**$6,534**	**$5,317**
Service Provider Cost	$6,921	$6,181	$5,454	$4,777
Consumer Cost	$2,160	$1,620	$1,080	$540

Table 12: Total investment required to deploy G-PON across the 75% of urban New Zealand.

Of this total, the fixed investment component varies from about 43 to 73%, depending largely on uptake, with the high percentages corresponding to the lowest uptake. This again highlights the issues associated with the domination of fixed costs, especially at low penetrations of service. It should also be noted that the consumer costs are a significant proportion of the total investment, especially at the higher levels of penetration. For the high cost scenario the consumers are contributing around 23% of the total investment in the current models.

Furthermore, it would be possible to increase the proportion paid directly by consumers if desired, by forcing them to also pay for the passive variable cost, or the cost of the premise lead-in. This would increase the consumer contribution to over 40% for the high cost scenario. However, it is doubtful that this approach would lead to high levels of take-up, as consumers would be reluctant to pay this type of premium for fibre based broadband services.

9.2.Total Investment for AEF Deployment

If AEF was to be deployed, such that it passed all 1.44 million premises and all 100% of these premises were to be connected and provided with service, then the likely cost for such a deployment would be represented by the figures contained in column 2 of Table 13. The other columns show the change in investment required when all premises are passed but the take-up of service is reduced from 100% down to 25%.

Table 13 illustrates the increase in investment required to deliver the services using AEF as compared to G-PON. However, as indicated previously, it is likely that any realistic deployment of fibre based infrastructure would include a mix of both technologies to meet the specific needs of different market segments. Hence the real investment requirements would lie somewhere between those indicated in Tables 12 and 13.

Low Cost Scenario				
Uptake	**100%**	**75%**	**50%**	**25%**
Passive Fixed Cost	$2,294	$2,294	$2,294	$2,294
Passive Variable Cost	$1,146	$860	$573	$287
Active Variable Cost	$1,920	$1,620	$1,320	$1,020
Service Provider Cost	$1,440	$1,260	$1,080	$900
Consumer Cost	$480	$360	$240	$120
Total Cost (NZD Millions)	**$5,361**	**$4,774**	**$4,187**	**$3,601**
Service Provider Cost	$4,881	$4,414	$3,947	$3,481
Consumer Cost	$480	$360	$240	$120
Medium Cost Scenario				
Uptake	**100%**	**75%**	**50%**	**25%**
Passive Fixed Cost	$3,050	$3,050	$3,050	$3,050
Passive Variable Cost	$1,449	$1,087	$724	$362
Active Variable Cost	$3,120	$2,520	$1,920	$1,320
Service Provider Cost	$1,920	$1,620	$1,320	$1,020
Consumer Cost	$1,200	$900	$600	$300
Total Cost (NZD Millions)	**$7,619**	**$6,657**	**$5,695**	**$4,732**
Service Provider Cost	$6,419	$5,757	$5,095	$4,432
Consumer Cost	$1,200	$900	$600	$300

High Cost Scenario				
Uptake	**100%**	**75%**	**50%**	**25%**
Passive Fixed Cost	$3,927	$3,927	$3,927	$3,927
Passive Variable Cost	$1,809	$1,357	$904	$452
Active Variable Cost	$4,680	$3,690	$2,700	$1,710
Service Provider Cost	$2,520	$2,070	$1,620	$1,170
Consumer Cost	$2,160	$1,620	$1,080	$540
Total Cost (NZD Millions)	**$10,416**	**$8,974**	**$7,532**	**$6,089**
Service Provider Cost	$8,256	$7,354	$6,452	$5,549
Consumer Cost	$2,160	$1,620	$1,080	$540

Table 13: Total investment required to deploy AEF across the 75% of urban New Zealand.

10. Regional Aggregation

All of the above analysis has related to the provision of fibre in the first 1-2km from the customer premise. The analysis assumes that the fibre infrastructure throughout the remainder of the network is highly competitive and so requires no further intervention relative to normal market dynamics. However, outside of the 3-4 largest population centres in New Zealand, there are still some limitations in terms of fibre capability. This relates to what is often referred to as the regional aggregation component of the network. This is the part of the network where the access as described in this report is aggregated together across an urban centre to connect into the fibre based core network which provides connectivity up and down the length and breadth of the country. This regional aggregation is highly constrained in terms of capacity in many urban centres and even if it is not constrained in terms of capacity is typically subject to low competition and hence is highly priced. Consideration needs to be given to addressing this issue in parallel with the FTTP deployment in order to achieve the best possible outcome.

11. Improving The Cost Models

The above cost models provide a useful guide to the unit costs and investment required to provide fibre coverage of 75% of premises in urban New Zealand. The models developed provide some useful bounds for the likely values to be expected in practice and together with the associated spreadsheet provide a wide variety of the assumptions involved in making these estimates. However, it is fully accepted that these models are based on substantial averaging of the real costs which would be encountered in an actual deployment. The actual costs encountered within any particular region should sit within the bounds defined in these models, but the number of regions that will exhibit different costs within the ranges defined is only understood on an average basis.

In order to make an improved assessment of the actual costs expected for any particular region it would be necessary to undertake a more detailed geographic breakdown of the region to be covered. Ideally the proposed coverage area should be broken down into blocks, with each block being defined by the most likely deployment approach for that block. This is likely to result in blocks consisting of around 10,000 to 15,000 residential and business premises. This approach might require the definition of over 100 blocks to cover urban New Zealand. Then each defined block would be modeled in terms of the optimum deployment approach for each block. This approach would amount to a basic high level design for the fibre deployment.

Furthermore, when taking this approach, the blocks could be readily ranked in order of cost and separately in order of income. This is exactly what any rational deployment entity would do. They would then deploy in order of the combination of lowest cost and highest revenue potential. This approach may well lead to the definition of a 75% coverage area which is quite different to that which would apply to the averaged models used in this report. In addition, it would be possible for such a modeling approach to define an affordability target – how much of urban New Zealand can be covered with a given commitment of investment?

This approach is strongly recommended as the next step in any refinement of costs and investment requirements. It is the only known practical approach to achieving a more robust assessment of the costs than that provided in this report.

12. Conclusions

The cost of deploying fibre-to-the-premise across the urban access network in New Zealand has been investigated. Two primary technology approaches have been analyzed, being Passive Optical Networking and Active Ethernet over Fibre. In practical deployment, it is acknowledged that both technologies would be used in combination to meet the total needs of the market, with AEF being used to meet the needs of business users and PON being used to meet the needs of residential users. However, for the purposes of modeling each has been analyzed separately.

The analysis has investigated a variety of assumptions and derived a number of variables for each deployment technology. These variables illustrate the likely variation in both unit costs and total investment that is likely to be encountered under a practical deployment across 75% of premises in New Zealand all located within urban areas. No attempt has been made to deal with the many additional issues which would be encountered for deployment into rural New Zealand.

Based on these assumptions, the models provide the likely range of costs and investment which will be incurred for a practical rollout of FTTP across urban New Zealand. No single number can represent the likely cost per premise passed, cost per premise connected or investment for premises passed or connected. There is a range of numbers depending on the assumptions chosen.

The results for a G-PON deployment to cover 75% of premises located within urban New Zealand can be summarized as follows:

- The fixed passive cost per home passed can be expected to lie in the range of $1700 to $2400,
- The variable passive cost per home connected can be expected to lie in the range of $800 to $1200,
- The variable active cost per premise connected can be expected to lie in the range of $1200 to $2400,
- The fixed passive investment required for coverage of urban New Zealand premises (75% of NZ premises) can be expected to be in the range of $2.6B to $3.3B
- The total investment required for connection of urban New Zealand premises with a take-up of 100% within the coverage area can be expected to lie in the range of $5B to $7.5B.
- The total investment required for connection of urban New Zealand premises with a take-up of 50% within the coverage area can be expected to lie in the range of $3.5B to $5.5B

The results for the AEF deployment are similar to those for the G-PON deployment except that:

- The fixed passive infrastructure unit costs and investment are about 5% higher than that for G-PON,
- The active infrastructure unit costs and investment are about 10% higher than that for G-PON,
- The total infrastructure unit costs and investment are about 15% higher than that for G-PON.

This study also shows that:

- It is very challenging to achieve a premises passed unit cost of substantially less than $2000, even using low cost deployment techniques to the greatest extent possible,
- The government's proposed investment of $1.5B will provide about 50% of the investment required to deliver fibre passed 75% of New Zealand premises,
- The cost of connecting a premise remains a substantial component of the total cost of deployment for FTTP, even after the premises have been passed by fibre infrastructure.

Given the above analysis, it is obvious that the lowest possible deployment costs are required for the passive components of the infrastructure, consistent with sound deployment practices to minimize investment in a FTTP rollout for New Zealand. This suggests the need to maximize the use of the following two types of fibre deployment:

- Aerial,
- Micro trenching,
- Intelligent directional drilling (a very new approach).

Based on this need it is recommended that further investigation and analysis of these technologies be undertaken as indicated below.

In addition to the above, it is recognized that the current models still have significant limitations in terms of an accurate assessment of the likely cost of providing an FTTP solution to the lowest cost 75% of premises in New Zealand. In order to further improve the accuracy and usefulness of the modeling, one would need to take another step towards the detailed design of a fibre rollout. This would involve dividing the coverage area into blocks, each of which had some consistency in terms of deployment characteristics – for example blocks suitable for mainly aerial deployment or mainly micro trenching. Then a first order optimal design could be done for each block. Furthermore, as with an actual rollout, blocks could be selected on the basis of cost for inclusion into the final coverage area, in order to determine the cost for deployment to the lowest cost 75% of premises in New Zealand. This approach could readily be implemented with known data sources, but would take at least an order of magnitude more time to complete than the current exercise.

13. Recommendations

Based on the above conclusions, it is recommended that:

- A uniform policy be established for the use of aerial plant across New Zealand urban areas, which clearly defines where aerial plant can be used and where it cannot,
- A set of best practice guidelines be established for aerial deployment, where aerial plant is available for use,
- A pilot of micro trenching be funded by Central Government to determine the best practice guidelines to be applied nationwide,
- The applicability and costs for intelligent directional drilling be investigated thoroughly and then be reflected into updated cost models,
- A more detailed cost modeling exercise be undertaken based on a block based high level solution design, in order to identify the investment required to serve the lowest cost 75% of premises in New Zealand,
- It be recognized that such an exercise will cost some hundreds of thousands of dollars to complete.

14. Appendix A: Glossary

AEF	Active Ethernet over Fibre
ADSL2+	Asynchronous Digital Subscriber Line version 2 plus
B-PON	Broadband Passive Optical networking
CBD	Central Business District
CO	Central Office
DSL	Digital Subscriber Line
E-PON	Ethernet Passive Optical networking
FTTB	Fibre-to-the-Business
FTTC	Fibre-to-the-Cabinet
FTTF	Fibre-to-the-Farm
FTTH	Fibre-to-the-Home
FTTK	Fibre-to-the-Kerb

FTTP	Fibre-to-the-Premise
G-PON	Gigabit Passive Optical Networking
Km	Kilometers
mm	Millimeters
NG-PON	Next Generation Passive Optical Networking
NZ	New Zealand
NZD	New Zealand Dollars
OLT	Optical Line Terminal
ONT	Optical Network Terminal
PON	Passive Optical Networking
STB	Set Top Box
TCO	Total Cost of Ownership
USD	United States Dollars
VDSL2	Very High Speed Digital Subscriber Line version 2
WDM-PON	Wavelength Division Multiplexing Passive Optical Networking