Assessment of Current State of Guidelines, Codes, and Legislation for Deployment of Fibre Optic Cable in Canada

by

Mudasir Mir

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Department of Civil and Environmental Engineering
University of Alberta

Abstract

Fibre optic technology has become the primary network infrastructure and a communication medium, which provides higher bandwidth capacity for current and next-generation technologies. While the demand for new technology and services increases, fibre optics technology brings the promise of a flexible, scalable, full-service network platform with potentially unlimited capacity. Over the years the Canadian fibre deployment continued, increasing the availability of fibre-to-the-home (FTTH) Internet services from 35.1% to 44.0% in 2018 (CRTC, 2019). Sustaining this growth hinges on efficient infrastructure deployment and well-organized end-to-end management. The Canadian fibre optic network and transmission system has challenges such as inconsistency in codification, installation difficulties, initial deployment cost and a fragmented right-of-way framework. With multiple stakeholders — including large corporate players and government agencies — involved in reaching the desired goal of digital transformation, a robust policy framework for development of optical fibre network infrastructure that also governs deployment is needed.

Local municipal governments across Canada are well-positioned to influence this digital transformation, including efficient and sustainable deployment of fibre optic cable within their jurisdictions, through accelerating planned programs and, most importantly, codification. A detailed analysis of the challenges related to the deployment of fibre optic cable is required with the aim of understanding the deployment risks including costs overruns associated with management of the right-of-way and utility relocation. The data collected from the literature review related to deployment of fibre optic cable using trenchless technologies was gathered and reviewed against multiple facets and across various industry verticals. This review was primarily focused on available municipal bylaws and guidelines, industry best practices, and completed projects targeting municipalities, provincial and/or state departments, utility providers, contractors, design consultants, and equipment manufacturers and suppliers. Based on the data screening and analysis, a questionnaire was generated and administered as a pilot version of an online survey to a close group of professionals. This industry-specific survey was conducted to understand the current state of guidelines, codes, and legislation for deployment of fibre optic cable. The core of the survey focused on the available guidelines in securing proper right-of-way permits. Further, the survey was designed to determine the type of deployment method and associated interface with existing underground utilities (such as buried cables and pipes). In addition, one section of the survey included questions about high-level capital expenditure components and the variation between urban and rural projects. The key objectives of this work are discussed in correlation with the findings from the survey, industry best practices and existing literature. Finally, suggestions are made to address the digital divide prevalent in the Canadian digital landscape.

Preface

This thesis is an original work by Mudasir Mir. The online survey which forms part of the thesis, "Current State Assessment of Guidelines, Codes and Legislation for Fibre Optic Cable Deployment (Pro00107518)," received research ethics approval from the University of Alberta, "Research Ethics Board 2" on January 27, 2022.

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for His blessing bestowed on me during this research.

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Chapter 1 : Introduction

1.1 Background

Civilizations were drawn to rivers for the many advantages to the human race these locations provided including efficient communication. Industrialization forced the development of settlements around the highway; however, in the current times, they cluster based on the availability of next-generation infrastructure, in particular fibre optic networks. The promise of technologies such as self-driving cars, virtual reality, delivery drones, and comprehensive home automation comes hand in hand with the explosion of 5G small cells catering dense urban areas such as downtown, stadiums, train stations, malls, etc. Canadians continue to subscribe to high-speed internet exhibited by a steady increase with 9.8 million subscribers in Q1 2014 to 12.1 million in Q1 2022 (CRTC, 2022). Demand for high speed data transmission has grown and this year-over-year spike in demand can no longer be supported by traditional copper networks, due to their limited data transmission capacity. Hence, providing broadband access for the internet of things (IoT) through the backbone fibre optic network to overcome this restriction has become essential for internet service providers around the globe. Only 25% of households have the option of fibre to the home (FTTH) and, in the United States, rural areas are still underserved or not served at all. The top three reasons given as to why deployment is not speeding up include distance, cost overruns and installation barriers like environmental obstacles (Canevaro, 2018).

While fibre optic technologies have tremendous operational capacity, the main limitation in its deployment is the cost and logistics of deploying fibre optic cable. Over the past five years, the cost of deploying fibre optic cable has come down, in addition to the purchasing price of the fibre optic cable itself. The cost of deploying fibre optic cable in the USA was up to 70K USD per kilometer in 2018, depending on the location; five years before (2013), this was closer to 100K USD (Saunders, 2018). One of the major hurdles to fibre optic connectivity in Canada is infrastructure provisioning. There is not enough fibre deployed across Canada to bridge the digital divide and enable smart utilities. The availability of fibre-to-the-home (FTTH) internet services in Canada increased from 35.1% to 44.0% year over year from 2018 to 2019, mainly in large urban areas (CRTC, 2019). It is critical to bring awareness and identify different solutions to improve network reliability, wireless connectivity, and corporate management. This research attempts to highlight the pain points in the adoption of advanced trenchless techniques available for expansion of fibre optic networks — each of which has its own benefits and drawbacks. The most common installation techniques include trenched installations (i.e., open cut) and installation using trenchless methods such as horizontal directional drilling (HDD). It is important to gain an understanding of the condition of fibre optic industry in the context of multiple stakeholder expectations, right-of-way (ROW) regulations and available installation codes or guidelines.

1.2 Problem Statement

Previous studies have been conducted to address the digital divide that many remote and rural indigenous communities across Canada experience against the backdrop of policy, regulatory, and competitive challenges that both small and large internet service providers (ISPs) face in providing services (McNally et al, 2018), however the challenges related to the deployment of fibre optic cable have generally not been discussed. Fibre optic network, transmission and deployment in Canada involves multiple challenges — such as installation difficulties, finding the initial capital for installation, and (most importantly) a regulatory policy that governs the deployment of optical cable using micro trenching as a deployment method. The mandate of 50 Mbps upload/10 Mbps download internet is available to 87% of Canadians. However, only 37.2% of rural communities and 27.7% of First Nations reserve areas have access to the faster speeds of 50/10 Mbps, demonstrating a divide between the various communities for faster broadband services. Fibre deployment continued in 2019 across urban Canada, with the availability of fibre-to-the-home (FTTH) increasing from 44.0% to 44.7% (2018 to 2019) of households. These deployments were mainly in large urban areas. While fibre optic technologies have tremendous operational capacity, the main limitation in its deployment is the cost and logistics.

1.3 Research Objectives

This research seeks to investigate the challenges with fibre cable deployment in Canada, with an emphasis on the technical and regulatory challenges. In addition, the work includes recommendations for appropriate scholarly solutions to address the lack of regulatory guidelines and policies on fibre deployment and management in Canada. The main objectives of this thesis are as follows:

Objective 1: Investigate the challenges with fibre optic cable deployment in Canada, with an emphasis on the lack of regulatory guidelines and policies using Micro trenching as a fibre optic cable deployment method in Canada.

Objective 2: Investigate the condition of fibre optic industry in the context of right-of-way (ROW) regulations and the challenges in mapping accurate data related to existing underground utilities that impede the growth of fibre infrastructure. In addition, address the gaps in enforcing the dig-once policy and co-deployment as they remain critical to the deployment of fibre infrastructure.

1.4 Research Methodology

A review of multiple facets of the deployment of fibre optic cable using micro trenching technology was carried out for 42 unique cases targeting various industry verticals globally (Municipalities, provincial /state departments, utility providers, contractors, design consultants & equipment manufacturers and suppliers). These cases were investigated and analyzed, with duplicate and redundant information removed from the analysis. Based on the data screening and analysis of the cases, 28 questions (Appendix I) were developed and included in an online survey. This survey was a pilot version, and was sent to a close group of 76 professionals (comprising Canadian utility owners and service providers, design consultants, build contractors and manufacturers) using an online survey platform (Survey Monkey). The survey, titled "Current State Assessment of Guidelines, Codes and Legislation for Fibre Optic Cable Deployment (Pro00107518), and the associated methodology and communications were approved by the

University of Alberta Research Ethics Board 2. The core of the survey focused on available codes, guidelines and legislation across Canada related to securing the proper right-of-way permits. Further, the survey aimed to determine the type of deployment method, as well as the coordination with existing underground utilities such as buried cables and pipes. In addition, a section of survey dealt with the variation in capital expenditures between urban and rural fibre projects. This survey was based on qualitative research methods, and is expected to be beneficial for the telecommunication industry, including contractors and governing bodies in particular (e.g., municipalities and provinces) in developing or refining the legislative framework for emerging technologies related to fibre optic deployment. The survey is organized in four distinct sections: Demographics, Deployment Techniques, Deployment Costs and finally Codes, Regulations and Standards. The frequency of occurrence is estimated and collected from the raw data using a scale analysis matrix. The research is expected to gain an in-depth information about the reasoning and motivations underlying the fiber industry by screening and analyzing the survey results to come up with the final availability (as a percentage) of deployment techniques, costs and codes, regulations and standards. Both the findings from literature review and the pilot survey were used to make suggestions on addressing the gaps within the Canadian fibre optic industry. The responses collected in this pilot version of the survey will form a baseline for improving a future survey with wider distribution, to potentially collect more comprehensive data from a wider selection of cities across Canada and North America, so that the number of projects carried out can be determined and compared against the baseline of available codes, guidelines and legislation for a particular jurisdiction. Further, the methodology structure is summarized in (Figure 1) below:

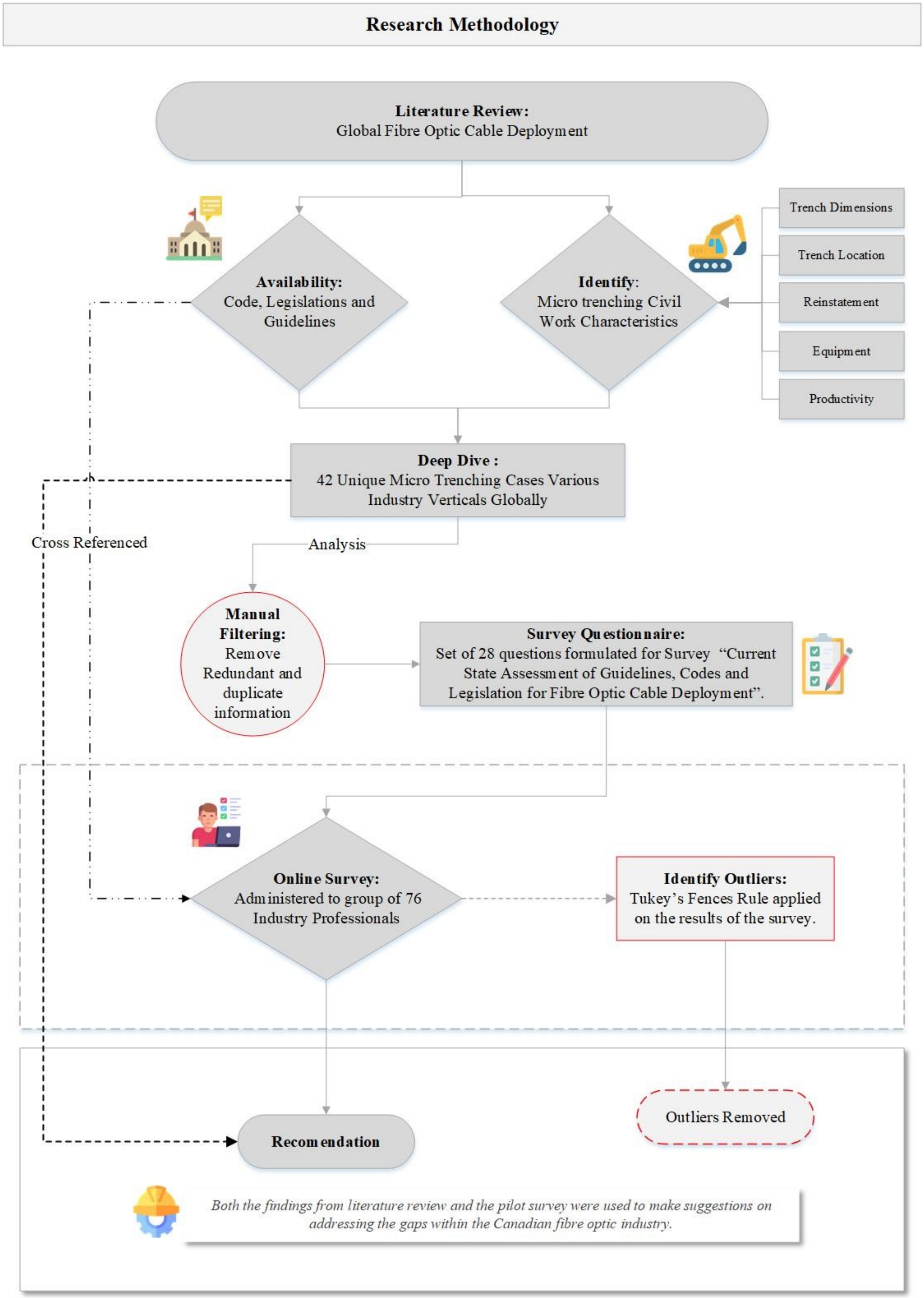


Figure 1. Research Methodology Schematic

1.5 Thesis Structure

The thesis consists of a total of six chapters. An overview of each chapter is given below:

Chapter 1 includes a brief background of issues related to the Canadian fibre optic network, in particular, transmission and deployment. This chapter also gives an overview of the objectives and scope of the research and describes the methodology used to achieve the outlined objectives. Finally, an overview of the thesis structure is given.

Chapter 2 gives an overview of the deployment of fibre optic cable around the world and compares the Canadian broadband footprint with fibre optic cable deployment. This chapter also includes a discussion related to corporate investments and the investments by various tiers of Government towards fibre optic deployment:

- The Connect to Innovate Program
- Broadband Fund
- Provincial commitments
- Corporate investments

Chapter 3 includes a summary of the dominant Canadian regulatory framework supporting fiber deployment, including the role of CRTC. Regulations related to right-of-way, co-deployment and dig-once policies are discussed. Finally, the major components of civil work involved in the deployment of fibre optic cables are discussed in relation with available guidelines.

Chapter 4 includes an analysis of global fiber deployment using trenchless construction methods. This chapter discusses the components of trenchless fiber deployment based on 42 cases, including outside-plant deployment and the associated civil construction costs.

Chapter 5 includes an assessment of the current state of fibre deployment in Canada. The qualitative analysis of the online survey results is discussed in detail. The discussion includes a summary of the industry-wide challenges associated with fibre deployment, including right-of-way, gaps in co-deployment and lack of codification. This chapter also includes a summary of the results of the survey.

Chapter 6 focuses on the conclusions drawn on the basis of outcomes from the previous chapters. In addition, potential areas for future research are suggested to further improve the Canadian fibre optic network; in particular, issued related to transmission and deployment. Finally, suggestions for future research that can be performed as continuation of the present work are given.

Chapter 2 : Global Fibre Deployment and The Canadian Broadband Footprint

2.1 Introduction:

The COVID-19 pandemic has intensified the need for reliable connectivity, from merely access to basic internet browsing to capacity and scale-based applications such as media streaming and video calling. Since 2019 the demand for broadband communication services has soared, with some operators experiencing as much as a 60% increase in Internet traffic compared to before the crisis (OECD, 2020). Fibre optic networks, including backhaul and access networks, have the capacity to provide low-maintenance broadband connectivity with multi-gigabit speeds. Investment in broadband positively affects economic growth and drives overall market competitiveness. An analysis of more than 200 studies on broadband impact by the International Telecommunications Union (ITU) notes that a the percentage increment in per capita gross domestic product (GDP), resulting from an increase in 10 per cent broadband penetration worldwide, has remained stable both for fixed (from 0.77 per cent to 0.80 per cent) and mobile broadband (from 1.50 per cent to 1.60 per cent) (International Telecommunication Union, 2021). Standardization of fibre network deployment plays a significant role in accomplishing broadband coverage by decommissioning of copper based infrastructure through copper to fiber migration initiatives that are environmentally sustainable. These standards typically include consideration related to right-of-way, adoption of co-deployment practices, depth of trenching, size of ducts (depending on the location), type of fibre cable and the selected deployment methods, among other factors.

2.2 Deployment of Fibre Optic Cable around the World

The 10 per cent broadband penetration worldwide (International Telecommunication Union, 2021) has resulted in fibre optic cable network expansion across the world. Many telecommunications companies around the world are on a well-placed strategic roadmap towards improved internet connectivity, voice communication, and the flexibility of interconnectivity. Over the next five years, the percentage of the global population that remains unconnected will drop from 42% to 30%. However, by 2026, 30% of the global population is expected to only access the internet via a mobile device; meaning that, in reality, only 40% will have the luxury of fixed broadband at home (OMDIA, 2021). Even for consumers that are connected to fixed networks, the type of service they receive is far from equal, especially when access is compared for different geographical locations. For example, in Latin America (where 44% of the population is expected to have access to fixed broadband services at home by 2026), only 5.3% of the population will be on a connection delivering 500 Mbps or more, and only 1% will have speeds of more than 1 Gbps. In contrast, in North America, the percentage of the population with broadband access is expected to be 77%, 26% (500 Mbps or more) and 11% (more than 1Gbps). For Oceania, East Asia, and South-East Asia, these are expected to be 66%, 40%, and 10%, respectively. At the other end of the spectrum, only 9% of the African population will have access to fixed broadband, with 84% of those users limited to speeds of less than 30 Mbps (OMDIA, 2021). Internet service providers of all sizes across the globe are taking advantage of the demand of high speed internet connectivity and therefore expanding market share through their networks. The three largest telecommunications companies in the Unites States – AT&T, Verizon and Quantum Fibre – are expanding their FTTH footprints (Broadband Communities, 2021). AT&T aims to more than double its fibre footprint in the coming years to reach 30 million customer locations in the United States by the end of 2025 (Goovaerts, 2021).

The main driver of this expansion is the decommission legacy copper networks, which not only saves costs on running expensive, inefficient legacy technology, but also allows capital and resources to be freed up and redeployed to focus on delivering gigabit broadband with the most efficient next generation technologies (fibre backhaul, 5G, and IoT) (Little, 2021). From the perspective of global fibre deployment, operators encounter numerous roadblocks that necessitate contributions from regulators and government bodies. These include aligning on key initiatives to accelerate the decommissioning of copper networks and realize efficiencies from the fibre network build, efficient right-of-way (ROW) accessibility, permitting process, and hence minimize construction costs (in particular civil costs). Dynamic policies play a key role in removing these roadblocks, and therefore collaboration between governments, regulators, and service providers must be fostered, for example, through use of existing government facilities, streetlights, ducts, and sharing of utility corridors.

2.3 Canadian Broadband Network Landscape

50 Mbps upload/10 Mbps download internet is available to 84.1% of Canadians. However, only 37.2% of rural communities and 27.7% of First Nations reserve areas have access to the faster speeds of 50/10 Mbps, demonstrating a divide between the various communities for faster broadband services. In the northern territories (Yukon, Northwest Territories and Nunavut), 50/10 Mbps unlimited broadband is completely unavailable (as of 2019), which further illustrates the

urban-rural divide in terms of access to service, especially at faster speeds (CRTC, 2019). Fibre deployment continued in 2019 across urban Canada, with the availability of fibre-to-the-home (FTTH) increasing from 44.0% to 44.7% (2018 to 2019) of households. These deployments were mainly in large urban areas. At the same time, availability of 50/10 service with unlimited data reached 87% of households, compared to 84.1% in 2017 (CRTC, 2019).

As part of their efforts to compete with cable-based carriers, incumbent telecommunications service providers (TSPs) (Bell, Rogers, Telus, Shaw, and Quebecor) continued to build FTTH networks and promote fibre-based internet services. This resulted in a significant increase in the share of fibre-based Internet service subscriptions to incumbent TSPs, which increased from 5.0% in 2014 to 14.5% in 2018 (CRTC, 2019). High-speed fibre internet has for the first time overtaken cable to become the primary fixed broadband technology across the OECD's 38 member countries with 34.9% of fixed broadband subscriptions (OECD, 2022). When it comes to the household availability of full fibre networks, in 2020 the household coverage in Canada (49%) was ahead of the US (42%), Australia (16%), UK (18%), Germany (11%), and Italy (34%) and the EU average of 43% (Innovation, Science and Economic Development Canada, 2022).

2.4 Global Broadband Investments

Globally, investment in broadband technology, infrastructure and networks is leading business opportunities and establishing new jobs. Research has shown that companies which adopt broadband-based processes can improve employee productivity. In Cornwall (United Kingdom), four years after the implementation of a regional broadband development program (actnow), the business services sector saw an increase of 10% in yearly growth and an annual increase of 7% in productivity compared to the rest of the United Kingdom (MICUS, 2008). In Chanute, Kansas, a municipal network provides a 10 Gbps fibre-optic broadband ring around the municipality, which generates $600,000 per year in leasing contracts with telecommunications providers, enabling the revenue to be reinvested in the network and the network to be upgraded (networks, 2012).

2.5 Capital Investments for Fibre Deployment in Canada

2.5.1 The Connect to Innovate program

The *Connect to Innovate Program*, launched by the federal government (Innovation, Science and Economic Development Canada) in December 2016 with an planned investment of $500 million by 2021, was planned with the objective of bringing high-speed Internet to 300 rural and remote communities in Canada. This includes laying more than 20,000 km of high-capacity fibre optic network across Canada. As of December 2021, 733 communities (~185,803 households) have been connected under the program. Further, $585 million has been committed under this program to improve connectivity in over 975 rural and remote communities, including 190 Indigenous communities, by 2023 (GOC, 2022). Similarly, the *Accelerated Investment Incentive* introduced in the Government of Canada’s 2018 Fall Economic Statement offers incentives to businesses and telecommunications to invest in fibre connectivity. Further, the *High-Speed Access for All, Canada’s Connectivity Strategy* provides $1.7 billion in new funding to build new high-speed networks across Canada, including fibre optic infrastructure (GOC, 2022).

2.5.2 *Broadband Fund*

The CRTC has set out a universal service objective for Canadians in urban, rural and remote areas to ensure fixed access to voice and broadband Internet access services (50 Mbps download speed and 10 Mbps upload speed) (CRTC, 2016). The path forward for Canada's digital economy is to close the remote/rural and urban digital divide. In order to meet this objective, existing infrastructure across Canada needs to be upgraded and new infrastructure needs to be built. This will require a great deal of time and money and a collective effort from all levels of government and the industry. The CRTC *Broadband Fund* has established a $750 million fund to help provide all Canadians with access to broadband Internet and mobile wireless services (CRTC, 2019).

2.5.3 *Provincial Funding Commitments for Broadband Access*

The Government of Ontario is committing nearly $4 billion towards broadband infrastructure to connect every region of the province with access to high-speed internet by the end of 2025. This proactive approach is the largest single investment in high-speed internet made by any provincial government in Canadian history (Ontario, 2022). Similarly, the Government of Alberta is committed to working with all levels of government and the private sector to increase investment into connectivity infrastructure in rural communities and achieve 100% connectivity by the end of the 2026/27 fiscal year. The Government of Alberta has secured an additional matching agreement with the Government of Canada. The total public investment has increased to $780 million, with $390 million each committed from the Province of Alberta and the Government of Canada (Strategy, 2022). Only 35% of rural Indigenous communities in BC and 33% of rural non-Indigenous communities in BC have access to 50/10 Mbps broadband service. The Government of British Columbia and Government of Canada have announced a partnership to invest up to $830 million to support connectivity infrastructure projects that will improve access to high-speed internet for underserved rural communities and First Nations in B.C. This builds on investments to date and includes $289 million announced in Budget 2022 (BC Government, 2022).

2.5.4 Corporate investments

At 24.3%, the telecommunications industry ranked fourth in terms of capital intensity. This is due to the requirement to maintain and upgrade extensive network infrastructure. The capital intensity of the Top 5 TSPs, Bell, Rogers, Shaw, TELUS, and Videotron, was 28.5%. These TSPs accounted for 82.2% of the total telecommunications CAPEX in 2018 (CRTC, 2019). In 2022, Bell is undertaking its most aggressive fibre buildout ever, with plans to reach up to 900,000 more homes and businesses across most of Canada with direct fibre connections. This project is part of Bell's historic two-year capital expenditure program of almost $10 billion, now in its second year, to accelerate the rollout of its broadband fibre, 5G and rural networks (Bell, 2022). TELUS has invested more than $175 billion in infrastructure since 2000, and will additionally invest approximately $40 billion over the next three years, for a total of $215 billion (Telus, 2022).

2.6 Conclusion

Fibre optic cable (FOC) is considered as an excellent transmission medium in telecommunications due to of its flexibility, higher bandwidth, long distance communication and least attenuation compared to electrical cables (Curran, 2015). Just like utilities like water or sewer network, the FO network is build out with expansion driven by IT needs and engineering as an enabler. FO cable is relatively cheap to procure and therefore deployment of surplus cable is recommended as the upfront cost is normally be lower than future deployments allowing the layering of new services as required without having to install a new FO cable which results in overall program control, cost savings and increased redundancy and reliability. Canada's vast landscape with varying geography and climate presents unique challenges in providing high-quality broadband internet access services for all Canadians. In particular, many rural and remote areas do not have services comparable in speed, capacity, quality or price to what is offered in urban centres. Program level control of a FO network is advantageous at both corporate and government levels, while strategic objectives and timelines may not always coincide. Local municipalities and other relevant authorities may factor in the long-term benefits of access to dark fibre, which primarily is unused fibre and available for use. FO networks built today prove to benefit residential and business users for in future.

Chapter 3 : Regulatory Framework supporting Fibre Deployment in Canada

3.1 Introduction

Canada, with its varying geography and climate, faces unique challenges in providing comparable broadband Internet access services for all Canadians. Deploying fibre optic cables comes with several technical challenges mainly along highways and through city streets. Deployment with varying soil types, unique site layouts in particular brownfield, planning fibre routes, and adhering to the planned routes becomes challenging. In this chapter, some of the big rock challenges are discussed in light of the available codes and industry best practices. Post-deployment fibre infrastructure management is a framework based on engineering principles with the objectives to preserve, operate, maintain, repair, and renew aging fibre build, while effective management of this infrastructure is essential to all the stakeholders (Tekin, 2016). In addition, fibre networks must be protected from intentional or unintentional acts of damage including vandalism, cuts, bends, and any form of activity that could potentially destroy the infrastructure. In 2016, Canadian Radio-television and Telecommunications Commission declared broadband internet a basic service means that broadband is now recognized as part of the country's universal service framework (CRTC, 2016). Service providers are required to contribute towards a universal service funds (USF) to support service expansion, but will be able to apply for funding through a competitive application process rather than being mandated to provide service (OECD, 2018).

3.2 Canadian Radio-Television Telecommunications Commission (CRTC)

Telecommunication is an exclusive federal jurisdiction in Canada. Sections 42-44 of the "Telecommunications Act" provide the right of access for carriers to enter public places in order to construct, maintain and operate their transmission lines. These provisions also confer power on the Canadian Radio-television Telecommunications Commission (CRTC) to grant carriers permission to construct lines, if they cannot obtain municipal consent on terms acceptable to them, and to resolve complaints by municipalities about carriers. Further, building code requirements for entrance cables have been laid down by the Canadian Electrical Code where the code under section 60, mandates the rules in the installation of communication wiring in a building.

3.3 Right-of-way for Fibre Deployment

Right-of-way acquisition to lay utilities like fibre optic cables is extremely time-consuming since the process involves the acquisition of a license to lay fibre optics cable along the public street which has direct consequences in the implementation timelines. Some cities in the United States have imposed aggressive cutoff date for approving or denying registrations to reduce the end to end cycle time. Other cities have authorized blanket permits, eliminating the need to require registration for each separate installation of facilities). States such as Kansas, Indiana, Ohio, and Florida prescribed 30-day deadlines for processing permits, while Michigan and Virginia established 45-day deadlines (Farmer, 2016).

3.3.1 Canadian Oil or Gas Pipeline Right-of-way

Federal and provincial authorities have regulatory jurisdiction over pipeline facilities. Within the jurisdiction of western Canada permits must be obtained from the pipeline owner and regulators for any ground disturbances including, but are not limited to digging, excavation, trenching, ditching, tunneling, boring or drilling etc. All construction work near an oil or gas pipeline operating in excess of 700 kPa (100 psi) requires an approved permit issued by the pipeline company prior to the commencement of any work (Utilities, 2021). Activities that are not considered to be a ground disturbance include a disturbance that is less than 30 cm deep and that does not reduce the pipeline cover to less than what currently exists, and cultivation less than 45 cm deep. Below are the acts and regulations in effect that safeguard the infrastructure at various federal and municipal levels:

Regulator	**Permits for the nature of work**
Canada Energy Regulator (CER) *Jurisdiction: pipelines that cross provincial or national borders.*	All work within the high pressure pipeline right of way or its projected limits across a road allowance (Canadian Energy Regulator, n.d.).
Alberta Energy Regulator (AER) *Jurisdiction: pipelines located within Alberta borders*	For CER and AER regulated areas, any work within 30 meters of the high pressure pipeline right of way or its projected limits. This includes facility placement paralleling the pipeline within 30-meter safety zone (Alberta Energy Regulator, n.d.).

BC Oil and Gas Commission (OGC) *Jurisdiction: pipelines located within BC borders*	For OGC regulated areas, any work within 40 meters of the high pressure pipeline right of way or its projected limits. This includes facility placement paralleling the pipeline within the 40 meter safety zone (BC Oil & Gas Commission, n.d.).

Table 3-1. Construction near an oil or gas pipeline

Depending on the application of the network the fibres should be protected and isolated from the environment considering crush resistance, tensile strength, temperature range, rodent protection, ultraviolet resistance, number of fibre strands required, etc. Often the pipeline route comprises a thin strip of land with an associated right of way that could allow telecommunication fibre cable to be buried directly in the ground, either together with the main pipeline or as a completely separate system with galvanized steel armor wires, or a lighter corrugated steel tape. Best practices recommended to place separate ducts or sub ducts for the future installation of fibre optic cables, either by pulling them into place or by blowing them in. Further, the pipeline operator to lease the duct space to a telecoms operator, without incurring the additional cost of actually installing the fibre optic cable.

3.3.2 Canadian Railway Right-of-way

Communication providers across the Prairies in Canada are frequently required to deploy communications cables (fibre or copper) across Canadian railway right-of-way. Under the Canadian Electrical Code, as well as various railway and transportation regulations, these crossings must meet specific technical requirements, intended to protect the affected railway infrastructure, as well as the communication plant. These regulations include the use of conduit or casing to house communication cables across the railways. The standard document that is most commonly referenced by regulatory agencies for these systems is CSA Standard C22.3, No. 7 (Canadian Standards Association, 2010). Construction procedures for railway crossings does not vary significantly for installations of conduit on other applications including roadway crossings. However, the performance requirements required by railway regulating authorities are more stringent. Many of the Canadian Pacific Railway properties contain buried parallel fibre optic networks. No cable crossings are to be installed at less than one (1) meter vertically above or below the fibre cables, and no buried parallel occupancies, poles or anchors are to be located within three (3) meters horizontally of the fibre optic cables. Overhead wire crossings must provide a minimum clearance of eight (8) meter above the top of rail (ATR) (Railway, 2021).

3.4 Planning the Fibre Optic Cable Deployment

Utmost care must be taken during the fibre cable installation procedure since glass fibres within the cables are highly sensitive to sudden bending, kinking, surging or impacting during the pulling operation, which under certain conditions may cause an increase in cable transmission losses which may not be revealed for up to two years after installation.

3.4.1 Marking Underground Facilities & Excavation

Within Canada, there are various municipal, provincial and federal laws and regulations that govern specific excavation requirements in areas such as Townships, Provincial, and National Parks. Excavation of public streets and highways involve specific hazards to workers and the public due to the location of the work, placement of equipment, vehicular, and pedestrian traffic.

The requirements for the excavation and placement of pre-cast manholes in accordance with regulations set by the Alberta Occupational Health and Safety Act (Government of Alberta, 2018). Location of manholes must be staked by a qualified surveyor, in accordance with detailed work plans, to avoid future litigation or lawsuits resulting from improper line assignments. Both Alberta and British Columbia currently have separate "First Call" or "Dial Before You Dig" organizations and each has their own procedures, materials and contact information. The location of each underground utility installation should be identified by the utility with stakes, paint or other temporary on-the-surface markings coded with an identifying color consistent with the uniform color code proposed by the Canadian Common Ground Alliance (CCGA). These colors are endorsed by the Canadian Standards Association in CSA S250-11 (CCGA, 2018).

	RED - Electric Power lines, Cable Conduit and Lighting cables
	YELLOW - Gas, Oil, Petroleum or Gaseous Materials
	ORANGE - Telephone Cable TV, Communication, Alarms and Signal
	BLUE - Water Mains and Service Lines
	GREEN - Sanitary Sewers, Storm Sewers, end Drain Lines
	PINK - Temporary Survey Markings
	PURPLE - Reclaimed water, irrigation and slurry lines
	WHITE - Proposed Excavation

Table 3-2. APWA uniform color code (Source: CCGA).

CCGA manages damage prevention issues of national interest in underground construction with its regional partners including publishing best practices followed by groups and corporations including excavators, road builders, public works and utility companies, telecommunication providers, oil, gas, railroad and equipment manufacturers. In 2020, more than 45 damages occurred per workday which translated into 11,573 total number of reported damages Canada-wide. Out of the total reported damages, natural gas and telecommunication facilities were affected in 83.4% of damages (40.9% and 42.6% respectively), while water and sewer systems accounted for 27% of damages. The most common known root cause of damages was excavation issue accounting to 36.7%.

Province	Telecom.	Gas	Electric	Water	Others
British Columbia	9%	84%	0%	0%	7%
Alberta	57%	15%	5%	2%	21%
Saskatchewan	28%	35%	36%	0%	1%
Manitoba	0%	48%	52%	0%	0%
Ontario	41%	53%	5%	0%	1%
Quebec	56%	36%	4%	0%	4%
Atlantic	0%	100%	0%	0%	0%
Canada	**43%**	**41%**	**7%**	**1%**	**8%**

Table 3-3. Percentage of Damages by Affected Facility by Province/Region 2020
(Source: DIRT Report 2020)

The reported root cause of the damage occurrence from 2017 to 2020 had been a slight year over year increase in damages due to excavation issues, but those saw a decline in 2020. Further breakout of the top 90% of root cause sub-categories, the variance is mostly dominated by a three-way split of unknown root cause (28%), no notifications made to “One-Call Centre” (24%), and improper excavation practices (22%) (CCGA, 2020).

3.4.2 Co-deployment and Dig Once strategy

Based on the comparative study on cost-benefit analysis of fibre-optic co-deployment with the Asian highway connectivity, the cost saving was calculated by comparing co-deployment costs with separated deployment costs. United Nations Economic and Social Commission for Asia and the Pacific concluded the cost of two-way separated deployment to be USD 12,984 per km, while the cost of two-way co-deployment as USD 5,605 per km. Thus, two-way co-deployment can save USD 7,379 per km, representing 56.83% of savings compared to separated deployment (ESCAP, 2018). The adoption of a "dig once" policy whereby fibre conduits are installed at the same time other municipal infrastructure (road, power, water and sewer) projects are undertaken. These policies can reduce the cost of future fibre deployments by as much as 90 percent. Adding fibre conduits as part of net new construction project results in overall cost increases. Dig once policies can also be coordinated with building codes and development plans so that fibre is put in place in new greenfield developments. Leveraging the "Dig Once Policy" to install fibre optic ducts, vaults and cables along with other utility providers results in cost saving and minimizes impact to roadways. Limiting how often trenching occurs on the roadway will saves money and preserves the integrity of the road. It is approximately 10 times more expensive to add infrastructure after installation has occurred (USDOT, 2012).

3.5 Civil work in the outside plant environment

Fiber optic cables are ruggedly designed and hardened to protect from extreme outside plant temperatures, moisture, and chemicals, additional protection to is provided when cables cross the roads, urban areas, railways, oil & gas pipelines, etc. Civil construction standards (e.g; vault sizing, conduit bending radius or pulling standards) for fibre optic cable deployment differs from the electrical standards referred to under the electrical code. It is estimated that between 60% and 80% of the capital costs of a fibre deployment project are due to civil work, ducts and cables (Owusu Nyarko-Boateng, 2020). Over the past 20 years' fibre optic cable has only been commonly used in the private sector and hence availability of skilled workforce required for this type of undertaking rearly available in the public sector. Government entities should ramp up the efforts in creation of a fibre standard specific to the organization based on the geography, specific stakeholders and their needs (Columbia, 2019). Budgets usually dictate building for immediate needs, but putting in a larger vault or some additional conduit or a cable with a larger fibre count can yield significant future savings as demand grows. Resulting in mitigation-related savings that may be lost to increased operational and maintenance costs.

Fiber optic cable is usually placed in a 25 to 40 mm inside diameter (ID) sub-duct which is placed into an existing larger diameter communications conduit. Most communications conduits can be fitted with three or four sub-ducts. Sub-ducts are often referred to as inner ducts. An inner duct provides a more efficient use of the conduit system space, with a clean low coefficient-of-friction pathway and an extra measure of mechanical protection for an optical cable (Underground Installation of Optic Fiber Cable Placing, 2017). The following table (5-4) breaks down the big ticket civil works. These unit's rates are generalized and based on the government of Alberta's Price averages and indexes for Alberta Transportation highway, bridge and water management construction tenders.

Major components of civil scope of work:	**Rate**
Locates Field walk-outs to determine selected fibre routing including locating services when underground facilities exist prior to the start of the build.	$200 per hour
Permitting Detailed engineering design and preparation of permit applications including all fees by permitting authorities related to permit applications. Local municipal and provincial regulations may be required i.e. additional environmental permitting and requirements evaluated as part of a detailed engineering design. In addition, specialized engineering, permitting, and incremental construction (material and labor) costs associated with crossings of railroads, bridges, and interstate / controlled access highways.	Cost + 15%
Trenching & restoration including labor, equipment and material. Manual trenching of soft soil, conduit placement, utility pole make-ready construction. Surface restoration includes all work area protection and traffic control measures inherent to all roadway construction activities.	$150 per meter
Trenching and restoration by hydro vac application	$400 per hour
Horizontal directional drilling including drilling equipment	$150 per meter
Additional provision sum for asphalt / concrete cutting and restoration	Cost + 20%
Conduit installation in trench including placement of conduits and service vaults	$15 per meter

Installation of supporting civil structure, e.g. manhole and concrete pad for FDH . Placing structure concrete cast, approximately 2m x 1.5m and placed 1m depth include surface pad.	$5000 each
Flagging & Traffic Control and waste disposal	Cost + 20%

Table 3-4. Civil works involved in FOC deployment

3.5.1 Site Survey and Inspection

A pre-built route survey, inspection and verification of details contained in pre-build drawings will ensure that potential problem areas are uncovered before the work kicks-off. Inspections are carried out to determine the optimum splice locations and duct assignments. Soil is verified and classified by digging a pilot hole every 1km along the proposed path including the verification and documentation of the above and below ground utility locations including but not limited to obstacles along the route, manhole locations road / rail crossings, interface with other services and any temporary or permanent structures near the proposed trench. Conformity to the standards laid out in CAN/CSA-250 is applicable to municipalities, surveyors, utilities, planners, designers, installers and contractors of underground utilities (CSA Group, 2012). Irrespective of the method of site assessment employed, soils should be classified using the following two standard practices:

1. ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2. ASTM D2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

3.5.2 Communication Ducts and Vaults

The key to success is a flexible, robust outside plant solution that makes it easy to deploy and maintain high-quality connectivity. CSA Standard C22.3 No. 7-06 notes that thermoplastic conduit shall be “resistant to the chemicals with which it is likely to come into contact”. Thermoplastic piping materials, generally, are very resistant to chemicals commonly found in the environment as well as a variety of manufactured chemicals. CSA Standard C22.3 No. 7 requires that the conduit be designed to take into account all “temperature induced stresses”. Temperature induced stresses can result from either internally generated heat sources (such as with electrical transmission lines) or temperature changes induced from the external pipe environment. Fibre cable can be routed through existing traffic signal conduit with small vaults and tight bend radii. However, as fibre counts and cable sizes increase, so does the required size of the conduit and vaults. Some micro trenching designs utilize very small vaults or direct buried splice cases and some micro trenching designs require full size vaults (ie 1.5m SVs) (Columbia, 2019). Table 5-6 below provides the acceptable communication duct & vault used in Canada.

Duct / Vault	**Specification**	**Size**
Polyvinyl Chloride (PVC)	Typically, orange in color, the PVC DBII comes in 10′ and 20′ lengths. At one end is a bell end with the next duct needing to be primed and glued as the pieces are fitted together.	Most common duct size is 100mm (4"), which can fit as many as four or five cables in this duct. elbows with bends of 22°, 45° and 90.

High Density Polyethylene (HDPE)	Conduit comes on a reel of single, duplex or triplex, usually used when sub-ducting or drilling due to its increased flexibility. Fusing an HDPE conduit is very different from gluing a PVC duct.	Anywhere from 32 mm all the way up to 100 mm in diameter
Communication vault	Larger than those used for electrical installations due to the added space required for slack loops, fibre cable splicing and their larger bend radii. Vaults should not be more than 200–250m apart	Slack storage coil is 30m to 40m with standard size of 1.2m to 1.5m SVs and for large commercial applications with dimensions of 3m x 1.5m x 2m.

Table 3-5. Communication duct & vault specifications

3.6 Conclusion

67% of rural Albertans and more than 80% of Indigenous communities do not have access to reliable high-speed internet at federal target speeds. This represents approximately 201,000 households, or 489,000 Albertans, who are at an economic disadvantage to their peers living in urban centres (Strategy, 2022). Various Federal and provincial initiatives are currently being implemented to reduce the digital divide, including plans aimed at providing all Canadians with affordable high speed internet packages. However, from an engineering perspective the applications of trenchless deployment could drastically reduce the cost, time and complexity otherwise associated with traditional trenching methods which in addition to being expensive, is a lengthy process. A Crew can install as much as a thousand meters of fibre per day (including restoration). Equipment manufacturer Ditch Witch claims productivity of 12 meters / minute (Kleineke, 2018). Fiber network can be completed with smaller crews and less equipment. With minimal impact to existing roadways, sidewalks and landscaping trenchless method provides a win-win situation for the municipalities and the local constituents. In order to complement the application of less invasive deployment, a Dig Once Policy for must be reviewed and enforced by every municipal and regulatory agency to support the inclusion of underground conduit, splice access boxes in road works, bridge or utility projects that involve the excavation of roadways, trenching on public rights of way, etc.

Chapter 4 : Analysis of Global Fibre Deployment using Micro Trenching Method

4.1 Introduction

Trenchless method of fibre deployment allows making a hole or assimilating a conduit between two locations with minimum disruption to the existing built environment above the ground and advancing the conventional approach of “digging” with higher accuracy and precision. This technology is widely used for placing new pipe, cable, or conduit in the ground between two defined points without continuous, open-cut excavation between them, or for renovating, replacing, and rehabilitating (Kramer, 1992). Utility lines (like water supply, gas line, sewerage, and tele-communication lines) build an underground utility networks with “No dig” principle with minimal disturbance to the existing natural condition of the soil, serving through underneath of the ground level. A policy formulation was formed between the National Electrical Contractors Association (NECA) and the Fibre Optic Association (FOA) to develop a measure to regulate the deployment of optical network infrastructure. These measures were part of the American National Standards Institute (ANSI) and the National Electrical Installation Standards program. The NECA/FOA-301 standard is unique and covers the installation and testing of the fibre optic cables (NECA/FOA, 2016). Similarly, in Japan, the law and policy on optical network infrastructure deployment focus on network performance, accessibility, price, and reliability (Tekin, 2016). Several studies have been conducted in the past towards the advancement of trenchless renewal, repair or rehabilitation techniques. This chapter focuses to review and analyze the documented practices in fiber optic cable deployment using micro-trenching technique as an innovative deployment method.

4.2 Fiber Laying Techniques

Optical fibers are mechanically very different from steel and copper cables, and the techniques for installing them are therefore significantly different. Fibers are not only extremely brittle, but also elastic to an extent. Fibers must be also be protected from tensile forces (axial), compressive forces and bending. The long term transmission characteristics of optical fiber depends on the installation procedures used. Fiber laying is a specialized discipline that has to be performed by trained and experience personnel.

4.2.1 Ducting & Trenching

The traditional method of laying optical fibers still used in most developing countries is ducting and trenching. This involves creating a trench through manual or mechanized soil excavation. This approach is preferred in countries where manual labor is cheap. Trench specifications are normally defined by local authorities and could be specified for each operator in countries with multiple operators. The trenching process needs careful control to make sure the trench floor does not have any kinks and is uniform, and trenches do not have major bends. Ducts are placed in the trenches and fiber is then blown through the ducts with specialized fiber blowers, using water or air. In air assisted fiber blowing, the blowers use compressed air to push fiber through ducts. It is standard practice to lay conduits, then draw inner ducts through the conduits and finally blow the fibers through the ducts. A common conduit size is 100 mm, but 150 mm conduits are also available.

4.2.2 Cables Buried Directly

This fiber laying technique consists of using specialized equipment to create tiny incisions in any surface including concrete and asphalt. The fiber cable with a protective covering is then laid and the groove is filled with epoxy. The protective covering protects the fiber against the tensile and compressive forces that fibers are commonly susceptible to. This technique is conceptually the same as micro trenching, but does not require ducting. The technique is commonly used in urban areas where right-of-way permissions for standard trenching and ducting can't be obtained. On farms, fiber cable should always be buried below the maximum depth reached by agricultural equipment. On the other hand, the burial depth on highway and road crossings should be enough to avoid cables being damaged due to maintenance activities and road grading. Generally, the depth for these cables would be 30 cm.

4.2.3 Aerial Method

Aerial fiber optic cables are installed using a technique similar than that used for copper telecommunication cables. It is however important to realize that the transmission characteristics of fiber is affected by compressive stress, tensile stress and bends, making it essential to ensure that cable sag is within acceptable limits. Messenger or support wires made from Galvanized Iron (GI) provide support for the fibers strung between GI, or other suitable poles. The lashing of fiber optic cable is done using two methods – the Stationary method and the Moving Reel method. With the Stationary method, the cable is pulled into place using cable blocks, while the Moving Reel method employs reel carrying vehicles on the entire route of the fiber.

4.2.4 Horizontal Directional Drilling

Horizontal Directional Drilling (HDD) is also referred to as directional boring, and is a trenchless technique used for installing conduits, underground pipes and cables. For this type of installation, a drilling rig that is launched from the surface is used to create a shallow arc along a predefined path. The impact on surrounding areas using this method is minimal and it is therefore preferred when excavating or trenching is not practical. It can be used for numerous soil conditions and jobs including landscape, road and river crossings. Some cities will only issue Right-of-Way (ROW) permissions for HDD based cable laying. The process is multi staged and the first step involves creating an entrance pit with a receiving hole. A pilot hole is then drilled through the designed path, after which the hole is enlarged (reamed) with a larger cutting tool known as the back reamer. The diameter of the reamer is determined by the size of the pipe to be pulled back through the hole. In the next stage, a casing pipe is placed in the enlarged hole by using the drill stem. A fully automatic gyro based drilling mechanism is used by advanced HDD machines. The American Society for Testing Materials (ASTM) publish two documents which adequately cover installation of thermoplastic pipes for HDD and trenched installations as follows:

- ASTM F-1962 – Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings.
- ASTM D-2321 - Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.

4.2.5 Micro Trenching Technology

Micro trenching does not create a deep trench in asphalt as does conventional trenching, but creates a shallow trench, typically 2 cm wide and 30 cm deep. Special micro tubes are then placed in the grooves and it is filled, typically with a cold asphalt. The fibers are then blown into the tubes. Micro-trenching is generally a convenient solution for installation in business districts and downtown areas due to low restoration costs. It is also an environmentally-friendly method which causes minimal surface scaring and disruption to the community. However, due to its shallow depth, installations may be easily impacted and damaged by thermal expansion/contraction, ground freeze/thaw cycles, and frost heave (Vaseli, 2015). Micro trenching can significantly reduce the cost, time and complexity associated with any traditional trenching methods. Smaller crews can be grouped efficiently and deployment can be completed with less equipment and less impact to community. Another subset method known as mini trenching uses mechanized equipment is used to create mini trenches in many different surfaces. This technique can be used on routes that contain asphalt surfaces such as sidewalks and roads. The technique is however not suitable for soil with cobbles or gravel, or sandy soil. This technique has an advantage over conventional cable laying methods in that it is much faster to execute. The cross-section and depth of the trench will depend on the number of ducts to be laid. While the cross-section varies between 7 and 15 cm, the depth is typically between 30 and 40 cm. Trenching, ducting, backfill operations and cleaning are all performed simultaneously when the fully automated method is used. When the standard and semi-automated methods are however employed, the operations are not done at the same time.

4.3 Past Studies on Micro Trenching

Micro-trenching is a new, less-invasive fibre optic deployment method used in business districts and congested urban areas as the environmental impacts and community disruption associated with its operations are significantly lower than that of traditional installation methods. However, due to its shallow depth, installations may be easily impacted and damaged by thermal expansion/contraction, ground freeze/thaw cycles, and frost heave (Vaseli, 2015). Since civil work is the most expensive part of the job, organizations often try to save money through micro trenching however there are noted future costs due to the damage it can cause to the roadway. Google deployed Fiber in a few Louisville neighborhoods, including the Highlands, Portland, Newburg and Belknap. The company used "nano-trenching," through which it laid fiber along roadways in trenches only a few inches deep. Residents complained about the technique because, months later, fiber cables were popping out of the trenches. (Elahi, 2019). Use of micro trenching can complement a fibre network, particularly for redundancy and last-mile building entries. The deployment does not create a deep trench in asphalt as does conventional trenching, but creates a shallow trench, typically 2 cm wide and 30 cm deep. Special micro tubes are then placed in the grooves and it is filled, typically with a cold asphalt. The fibre is then blown into the tubes. An administrative issue observed in the analysis is enforcing the different conditions laid down at various stages for trenching and the reinstatement. While specific tender conditions for protection of trench, lighting and providing safety to road users can be found, these conditions are not fulfilled properly. The other inherent defect is in the backfilling process and materials used. These problem can be tackled by substituting suitable material for entire backfill and compaction of pavement by vibratory rollers as per requirements (Freed, 2019).

4.4 Micro trenching Review Methodology

The literature review was carried out to understand the current state of micro trenching technique for the deployment of fibre optic cables with a focus on available municipal by laws & guidelines, industry best practices, and completed projects globally targeting various industry verticals (Municipalities, provincial /state departments, utility providers, contractors, design consultants & equipment manufacturers and suppliers).

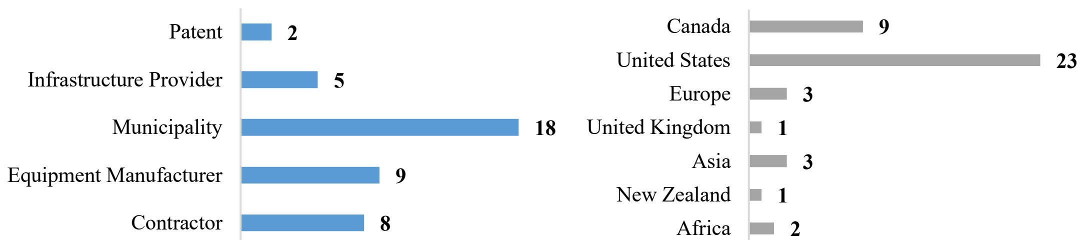
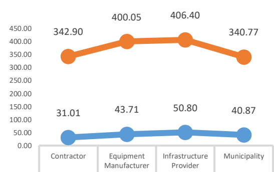


Table 4-1. Samples reported per industry vertical & location.

The first step involved the compilation and review of multiple facets of micro trenching technology over a samples size of 42 unique cases. Followed by a qualitative analysis of each reported case. Analysis of scenarios of engagement resulted in duplicate & redundant information, which were removed from the analysis. The next step involved categorization of each reported case under a best fit bucket i.e. classification (geographical region, industry vertical), trench dimension (width, depth), planning (procedure and location), deployment (duct placement, backfilling/ reinstatement, final sealing / cut filler, repair / maintenance, waste management, equipment, productivity). Finally, an outline of the findings along with a wireframe recommendation has been outlined.

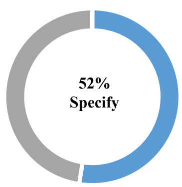
4.5 Summary of Observations

The review of multiple facets of fiber optic cable deployment using trenchless technology across various verticals over a samples size of 42 unique cases was carried out. These cases were investigated & analyzed, while duplicates & redundant cases were removed from the analysis Following table provides and overview of the observations:

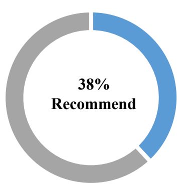


Average Median Width Range: 31.01 mm to 50.80 mm

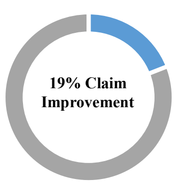
Average Median Depth Range: 340.77 mm to 406.40 mm



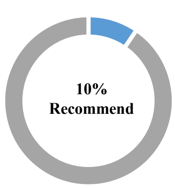
Trench Dimensions
22 out of 42 entities mention the trench sizes while 20 entities do not mention.



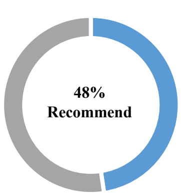
Equipment
16 out of the 42 entities recommend a trenching equipment, while the remaining 26 entities provide a generic statement.



Productivity
8 out of the 42 entities claim micro trenching to improve project timelines save the overall project cost while the remaining 34 entities provide a generic statement.



Trench Filler
4 out of the 42 entities recommend a reinstatement filler material, while the remaining 38 entities provide a generic statement.



Trench Location
20 out of the 42 entities recommend a trench location, out of which 8 entities recommend the carriage way.

Table 4-2. Trenchless deployment analysis

4.5.1 Trench Location

Four Canadian municipalities (City of Toronto, City of Calgary, City of New Westminster and Town of Cochrane) provide a general guidance about the placement of underground utilities in streets. According to the appendix X – Micro-trenching Guidelines (City of Toronto , 2018), the depth of the grooves shall not exceed the depth of the asphalt layer in composite pavements, meaning the grooves must not penetrate the concrete base to any extent. The City of Toronto does not permit micro-trenching on special pavements such as, decorative paving such as bricks, concrete pavers, exposed concrete, and so on. City of Calgary has a bylaw to control and regulate the use of streets in the city and to restrict and regulate activities on, adjacent, or near to streets (City of Calgary). An excavation permit is required to break or dig into the surface of a City of Calgary road right-of-way, as outlined in the streets bylaw. While the bylaw does not specify the location of micro trench in particular, however a general guideline around the placement of underground utilities in streets is provided. The bylaw demands a detailed engineering drawing of the facility and control devices indicating location, type, height above or depth below the surface of the street, and a detailed engineering report, signed and stamped by a Professional Engineer licensed to practice engineering in the Province of Alberta. The details must indicate the purpose of the facility, physical and chemical characteristics of the material, operating and maximum allowable pressures where applicable and a description of control devices for systems operations and procedures for containment of potential hazards which may affect public safety and the environment.

4.5.2 Trench Dimensions

According to the "Appendix X – Micro-trenching Guidelines" (City of Toronto , 2018), the ducts must be placed at least 55 mm below the surface of the pavement. The top of the upper most duct must be 55 mm or more below the pavement surface or extend beyond the asphalt layer for flexible pavements. Further, the asphalt depth as found in the field survey, the trench depth must be adjusted accordingly. City of New Westminster (British Columbia) issued drawings for tender (4th Street Backbone City Hall to Columbia Street, Phase -1) (City of Newwestminster, 2015), where a typical cross section indicates the width between 100 – 150 mm at depth of 610 mm . While on the south of the border the City and County of San Francisco (City and County of San Francisco, 2016), City of San Jose (City of San Jose, 2017), San Antonio (City of San Antonio, 2017) and Douglas County Public Utility District (Douglas County Public Utility District, 2018) provide an indicative trench dimensions. Further, Municipal Corporation of Greater Mumbai (India) published guidelines for trenching activity (MCB, 2015) where indicative dimensions are referenced. Department for Culture, Media and Sport (United Kingdom) via a document "Micro trenching and Street Works" (Department for Culture, Media and Sport, Government of United Kingdom, 2011) and Wallington Regional Strategy (Wallington Regional Strategy, 2017) via Wellington Region Broadband Plan provide an indicative trench width and depth related to fiver deployment using micro trenching method. Other industry verticals (Infrastructure Providers, Equipment Manufacturers & Contractors) confirm the best practices in relation to the trench width and depth.

4.5.3 Trench Filler

As per micro-trenching guidelines (City of Toronto , 2018), the micro-trench reinstatements require products that are free flowing to the bottom of the trench, self-compacting, simple and safe to use, obtains a high bond strength, stable under traffic load, suitable for the road environment, free of hazardous materials as defined in the City standards. In addition, City of Toronto outlines that upon completion of micro-trenching, lane markings and pedestrian walks shall be reinstated. City of San Antonio specify the filler to be polymer based controlled low strength materials (CLSM) / slurry with sealant on top (City of San Antonio, 2017). Nextec System AB, a contractor based in Sweden uses a start of art diamond trenching method (Davis, 2019). They recommend warm applied bitumen or thermoplastic based sealing material. Canadian equipment manufacturer Dura-line (Dura.line, n.d.) recommends "hot asphalt mixture" for the trench filler.

4.5.4 Equipment

While most of the entities in the collected sample including municipalities do not specify a requirement of a specific equipment, the City of San Antonio provides a generic statement to use "tractor with a hydraulic saw for street along the curb line and a hand saw for curb and sidewalk" (City of San Antonio, 2017). Major equipment manufacturers refer to their equipment line up fit for the different project scenarios (Ditch Witch micro trencher, Vermeer Micro trencher & vacuum excavator, Nextec Diamond micro trencher, Coneqtec's micro trenching attachments, Q-Trench System micro trencher, MARAIS's equipment combined on same chassis, trenching, vacuuming and waste storage).

4.5.5 Productivity

Based on the City of San Jose's strategy assessment, micro trenching and nano trenching can lead to labor cost savings of 25-50% which is primary cost driver (City of San Jose, 2017). Similarly, the City of Santa Cruz officials interviewed by the budget and legislative analyst stated that they expect to use micro trenching for as much as 80 percent of the project, which would substantially lower the estimated $40 - $45 million implementation cost to a lesser amount. However, streets in the City of Santa Cruz are primarily asphalt and therefore any success in using micro trenching there may not be applicable to San Francisco (City and County of San Francisco, 2016). Government of UK issued an advice note for local authorities and communication providers (Department for Culture, Media and Sport, Government of United Kingdom, 2011), where it has been concluded that using micro trenching method can save considerable time in deployment, as well as using fewer resources, reduced environmental impact with less waste removed from trenches and transported to the site for backfill. Micro trenching uses approximately one hundredth of the material needed to backfill the trench and where the technique is appropriate typical costs are in the order of approx. CAD $5 - $8 / meter and a single gang will typically complete 150-200 meter per day. Another study by Wallington Regional Strategy (Wallington Regional Strategy, 2017) states that the cost is roughly a half to quarter of traditional trenching costs with the added benefits of faster surveying and permit procedures. Using this method, a crew can lay as much as a 300 meter of fibre per day reducing road closure time. Information based on compact equipment comparison published by equipment manufacturer Ditch Witch, claims productivity of 12 meter / minute (Kleineke, 2018). French equipment manufacturer, MARAIS claims that construction costs are reduced by up to 70%. A deployment 5 to 10 times faster allowing a quicker implementation (Marais, n.d.). In a video interview (Butler, 2012), Idaho (USA) based contractor; Track Utilities, Inc. states that micro trenching was used to install more than 1,524 meter of fibre within the Jackson city limits. In areas where Track Utilities were cutting through 50 to 70 mm asphalt with three-quarter base underneath, they aver aged 150 to 210 meter a day. Taxes (USA) based contractor Quanta Services claims that the project timelines are reduced in half and hence the reduced cost by 75% (Quanta Telecommunication Services). New York (USA) based Contractor Corbell Communication Industries, claims productivity of 1220 meter / day (Corbel Communications Industries, n.d.).

4.6 Conclusion

In this analysis, five aspects of micro trenching technique used for the deployment of fibre optic cables are investigated. Based on the analyses, the following conclusions can be drawn: 20 out of the 42 (i.e. 48%) of the entities recommend a trench location, out of which 8 entities recommend the carriage way as desired for micro trenching. 22 out of 42 (i.e. 52%) of the entities mention the trench sizes while 20 entities do not mention. The average median width range is observed between 31.01 mm to 50.80 mm while the average median depth range is observed between 340.77 mm to 406.40 mm. 4 out of the 42 (i.e. 10%) of the entities recommend a reinstatement filler material, while the remaining 38 entities provide a generic statement. 16 out of the 42 (i.e. 38%) of the entities recommend trenching equipment, while the remaining 26 entities provide a generic statement. 8 out of the 42 (i.e. 19%) of the entities claim micro trenching to improve project timelines save the overall project cost while the remaining 34 entities provide a generic statement. Deployment of fibre optic cable and associated infrastructure is the globally preferred technology to supply high-speed broadband to end users. This technology is broadly used in backbone/ backhaul networks as well as in last-mile connectivity to support fixed and wireless broadband and is witnessing steady uptake across the world. However, multiple challenges related to right-of-way (ROW), lack of standards, unavailability of accurate data related to existing underground utilities, etc. impede the growth of fibre infrastructure. In addition, time bound permissions, robust Dig-Once policy, and uniformity of codes remain critical to the deployment of fibre infrastructure. Overall, micro trenching method is an appropriate alternative to the traditional methods of fibre optic cables deployment. It must be noted that this analysis is based on data collected within a condensed scope. A further study is still recommended with a possible broader coverage of completed projects and a comparative analysis of other fibre deployment methods.

Chapter 5 : Current State Assessment of Fibre Deployment in Canada

5.1 Introduction

Canadians continue to subscribe to high-speed internet exhibited by a steady increase with 9.8 million subscribers in Q1 2014 to 12.1 million in Q1 2022 (CRTC, 2022). To meet the demand for bandwidth, efficient deployment of telecommunications infrastructure with minimal impact (i.e. disruption to businesses/traffic, damage to existing infrastructure) various fibre deployment methods are used across Canada. However, the rapid pace of development and changes in the technologies used for fibre deployment have, in some cases, outperformed the regulatory framework and guidelines for their application.

In order to gain an understanding of the available guidelines, codes and legislations across in Canada related to the deployment of fibre optic cable within various jurisdictions of Canada and how they compare with one another an online survey was developed and administered to a close group of professionals (comprising Canadian utility owners and service providers, design consultants, build contractors and manufacturers) using an online survey platform (Survey Monkey). The core of the survey focused on available codes, guidelines and legislation across Canada related to securing the proper right-of-way permits. Further, the survey aimed to determine the type of deployment method, as well as the coordination with existing underground utilities such as buried cables and pipes. In addition, a section of survey dealt with the variation in capital expenditures between urban and rural fibre projects. This survey was based on qualitative research methods, and expected to be beneficial for the telecommunication industry, including contractors and governing bodies in particular (e.g., municipalities and provinces) in developing or refining the legislative framework for emerging technologies related to fibre optic deployment. The survey is organized in four distinct sections: Demographics, Deployment Techniques, Deployment Costs and finally Codes, Regulations and Standards. The frequency of occurrence is estimated and collected from the raw data using a scale analysis matrix. The research is expected to gain an in-depth information about the reasoning and motivations underlying the fiber industry by screening and analyzing the survey results to come up with the final availability (as a percentage) of deployment techniques, costs and codes, regulations and standards. Both the findings from literature review and the pilot survey were used to make suggestions on addressing the gaps within the Canadian fibre optic industry.

5.2 Objective of the Survey

There are many rural and remote indigenous communities in Canada that are still underserviced when it comes to internet connectivity. According to a new expert panel report from the Council of Canadian Academies, many people in rural and remote regions of Canada are still unable to access essential services online and struggle to thrive in an increasingly connected economy (The Council of Canadian Academie- CCA, 2021). This survey is a stepping stone towards the research in improving fibre optic deployment methods that will ultimately benefit these underserved communities by bringing the digital divide. Further, an understanding the current state of fibre optic cable deployment and the supporting legislative framework from the perspective of utility owners, contractors and municipalities can provide important groundwork for navigating the risks involved in fibre optic installation projects, resulting in improved construction guidelines.

5.3 Survey Methodology

Further to the review and analysis of global fibre deployment using trenchless methods discussed in chapter 3, the samples size of 42 unique cases were investigated & analyzed, while duplicates & redundant information was removed. Based on the data screening a condensed list of 28 questions (Survey questionnaire - Appendix I) was generated and further administered in a pilot version to a close group of 76 professionals (comprising of Canadian utility owners and service providers, design consultants, build contractors and manufacturers) through an online survey platform (Survey Monkey). The survey was approved by the University of Alberta's "Research Ethics Board 2". The core of the survey focused on of the available codes, guidelines and legislations around securing the proper right-of-way permits. Further, the survey targeted to determine the type of deployment method and associated interface with existing underground utilities such as buried cables, pipes. Among other variables, a section of survey inquired about the capital cost variation between the urban and rural projects. The survey is organized in four distinct four sections; demographics, deployment techniques, deployment costs and finally codes, regulations and standards. The probability and frequency of occurrence was estimated based on the collected data using a scale analysis matrix. The expected output summarizes the identified fibre optic cable deployment codes, guidelines and legislations against the identified objectives via a qualitative approach. Data was screened and analyzed to come up with the final availability (as a percentage) of each identified item among the respondents. Both the findings from literature review and the pilot survey is used to make suggestions to Canadian fibre optic industry on addressing the gaps.

5.3.1 The Questionnaire

The structure of the online survey is summarized in the Figure? below:

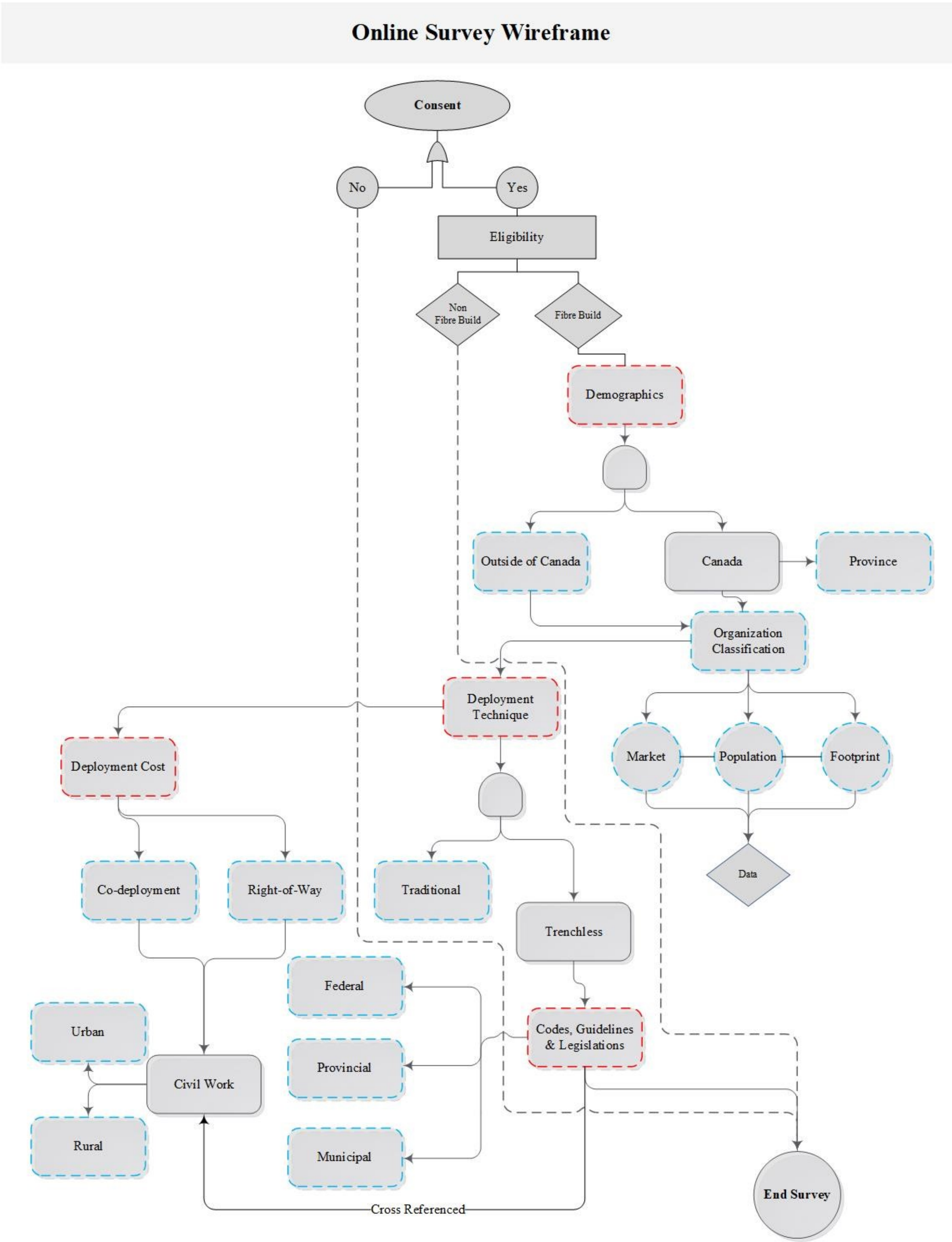


Figure 2. Survey Wireframe Schematic

Further, the survey is organized in 4 distinct sections:

1. *Section 1 - Demographics:* This section provides an overview of respondents based on geographical location of operations, market segmentation, industry vertical, etc.
2. *Section 2A - Deployment Techniques:* This section relates to the techniques used for fibre optic cable installations.
3. *Section 2B - Deployment Costs:* This section relates to the costs associated with fibre optic cable deployment for fixed broadband access infrastructure.
4. *Section 3 - Codes, Regulations and Standards:* This section contains questions related to currently applicable codes, guidelines and legislations (municipal, provincial and federal) related to end-to-end fibre optic cable installation.

5.3.2 The Respondents

Due to the specific subject of the survey, a specialized niche of industry professionals (infrastructure owners, internet service providers, municipal / local agencies, trenching equipment manufacturers, fibre optic suppliers, design consultants and contractors) with direct involvement to the subject area (telecommunications infrastructure deployment) were contacted across Canada. The inclusion criteria for potential participants was purely based on their involvement in the deployment of the fibre optic cable within residential or commercial consumer market. While the survey was sent out to 76 potential respondents, 27 responded with a response rate of 35.52%.

5.3.3 Data Screening

Once the Raw Database was established, data was then entered in Excel and further screened by using the Tukey's fences method to detect outliers, and to ensure consistency and to prevent potential skewness to the results after data analysis. The outlier screening summarized in (table 5-1) below was carried out using the following equation:

Q1 = first quartile value > 1/4 of the data *Upper limit = Q3 + 1.5*(IQR)*

Q3 = third quartile value > 3/4 of the data *Lower limit = Q1 - 1.5*(IQR)*

Where, the interquartile range (IQR) = Q3 - Q1

Data points that are not within the Upper/ Lower limits were then excluded from the next step. The output of this process is the Screened Database. Each response with a "Yes" answer is awarded 1 point, and a "No" answer is equivalent to 0 point. The frequency percentage is then calculated using the equation: *Frequency % = (Total points / Total number of interviewees) * 100%*

Survey Questionnaire		**Q1**	**Q3**	**IQR**	**U/L**	**L/L**	**Outlier**	**Data**
4	How would you classify your organization?	0.04	0.18	0.14	0.40	-0.18	None	NA
5	If you are an infrastructure or utility owner, how would you categorize your organization? (Please select all that apply)	0.00	0.05	0.05	0.12	-0.07	Telecom.	0.71
6	What size of population is served by your organization?	0.11	0.31	0.20	0.61	-0.19	<400,000	0.76
7	Please indicate which area(s) you mainly deploy networks in.	0.10	0.33	0.23	0.67	-0.25	urban & rural	0.85
10	Out of the following, which deployment projects does your organization support ?	0.46	0.7	0.24	1.06	0.1	None	NA
11	Is your organization involved in co-deployment of fibre optic cables along other infrastructure, such as roads, railway, and	0.13	0.63	0.50	1.38	-0.63	None	NA

	energy (e.g., gas, oil, or electricity) infrastructure? Please select the options that apply.								
12	Based on your experience, what are the benefits of co-deployment/co-habitation of fibre-optic cables along shared infrastructure routes?		0.13	0.61	0.48	1.33	-0.59	None	NA
13	Please rank the following fibre optic cable deployment methods used by your organization in order of frequency of use.1 = Most Common, 7 = Least Common Note: If factors are of equal importance, the same rating can be applied.	*Frequency Scale 1 (Most Common)*	0.09	0.30	0.21	0.62	-0.24	Aerial Method	0.70
		Frequency Scale 4 (Median)	0.06	0.11	0.05	0.19	-0.01	None	NA
		Frequency Scale 1 (Least Common)	0.11	0.38	0.27	0.79	-0.30	None	NA
14	Of the fibre optic deployment projects executed by your organization over the last five years, how often were trenchless construction methods used?		0.09	0.20	0.10	0.35	-0.06	Mostly (50% to ≤ 74%)	0.38
15	Please rank the following factors that affect the choice of utility deployment or replacement method for a specific project, in order of their importance = Most	*Frequency Scale 1 Most Important)*	0.13	0.36	0.23	0.70	-0.21	None	NA
		Frequency Scale 10	0.04	0.09	0.05	0.16	-0.02	None	NA

	Important, 10 = Least Important Note: If factors are of equal importance, the same rating can be applied.	*(Least Important)*						
19	The following question should be answered within the context of deploying fiber across your networks. Based on your experience in working with FTTx installations, what strategies are best to minimize deployment costs and thus increase return on investment?	*Urban Deployment*	0.51	0.93	0.42	1.57	-0.12	None	NA
		Rural Deployment	0.40	0.86	0.46	1.55	-0.29	None	NA
21	Within the jurisdictions that your organization undertakes projects, are there any existing guidelines, codes or regulations related to the following deployment methods? From the list below, please select all the available guidelines, codes and regulations related to your selected deployment method mandated by the federal / national, provincial / state and municipal / local jurisdiction of your project(s).	*Federal*	0.43	0.51	0.09	0.64	0.30	Micro trenching	0.28
		Provincial	0.52	0.69	0.17	0.95	0.27	None	NA
		Municipal	0.73	0.85	0.12	1.02	0.55	None	NA

22	From the list below, please select all the available guidelines, codes and regulations related to your selected deployment method mandated by the federal / national, provincial / state and municipal / local jurisdiction of your project.	*Federal Micro trenching*	0.00	0.04	0.04	0.09	-0.05	None	NA
		Provincial Micro trenching	0.00	0.00	0.00	0.00	0.00	OHS	0.08
		Municipal Micro trenching	0.00	0.00	0.00	0.00	0.00	Surface	0.20
23	Assuming that the municipal/local jurisdiction of your project does not mandate any guidelines, codes or regulations related to your selected deployment method, please select all the resources that would be used by your organization.		0.39	0.67	0.27	1.08	-0.02	None	NA

Table 5-1. Tukey's Fence Data Screening

5.4 Survey Results & Discussion

5.4.1 Section 1 - Demographics Segmentation

5.4.1.1 Respondents provinces and/or territories of operations, organizational classification and category of operations:

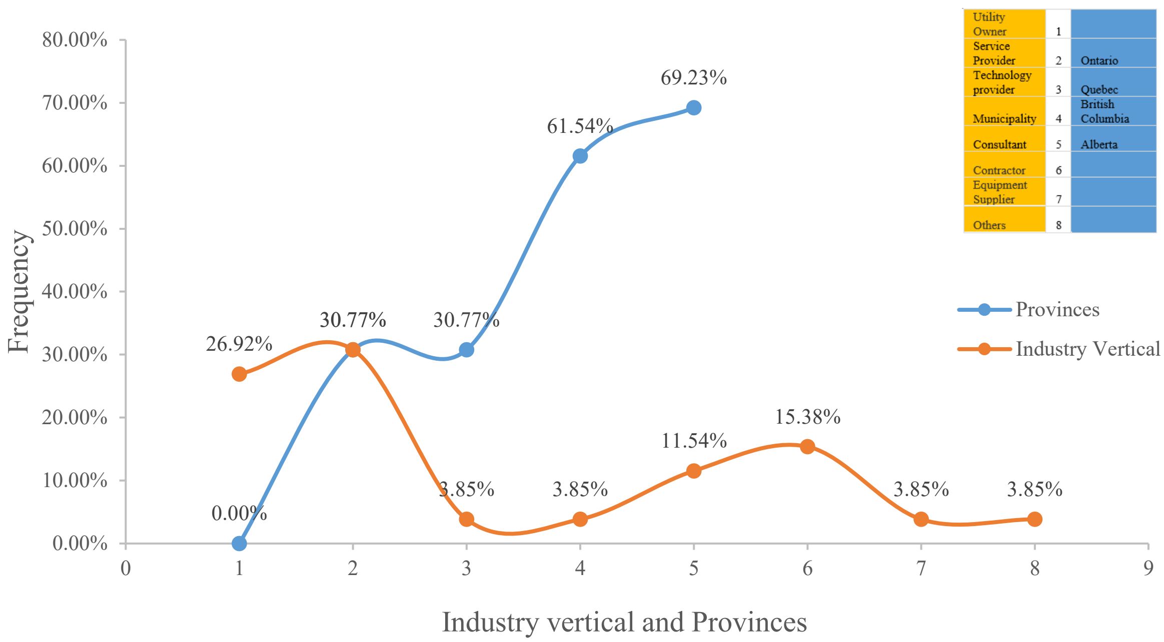


Figure 3. Respondents industry vertical and Provinces of operations

Out of the 27 respondents, i.e. 69.23% identified their project operations within Alberta, 61.54% within British Columbia and further, 61.54% of the respondents identified within Ontario and Quebec. 26.92% respondents identified their organizations as utility owners and 30.77% as service provider. 15 out of 27 respondents identified their organization as telecommunication service providers.

5.4.1.2 Size of population served by projects, area of primary networks deployment and primary market segmentation:

Out of the 27 respondents in this sample, 76% served the very large population category (more than 400,000 people) with 84% of their operations in both urban and rural areas. Further 92.31% serving both business and residential customer base.

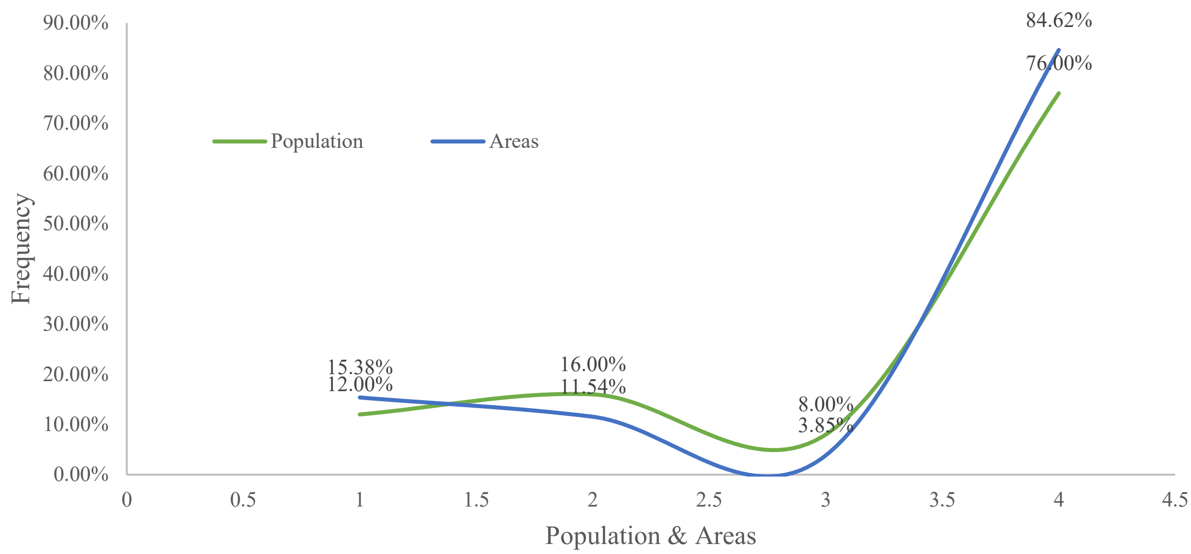


Figure 4. Population size Vs Operational footprint

5.4.2 Section 2A - Deployment Techniques

5.4.2.1 Role in deployment of fibre optic cables directly Vs indirectly:

45.83% of the respondents identified their organizations involvement in deployment of fibre optic cables as direct (e.g., contractor who performs installations) while 54.17% respondents indicated their organization were indirectly involved (e.g., municipality who issues permits, service provider who contracts out fibre deployment, etc.).

5.4.2.2 Type of deployment projects:

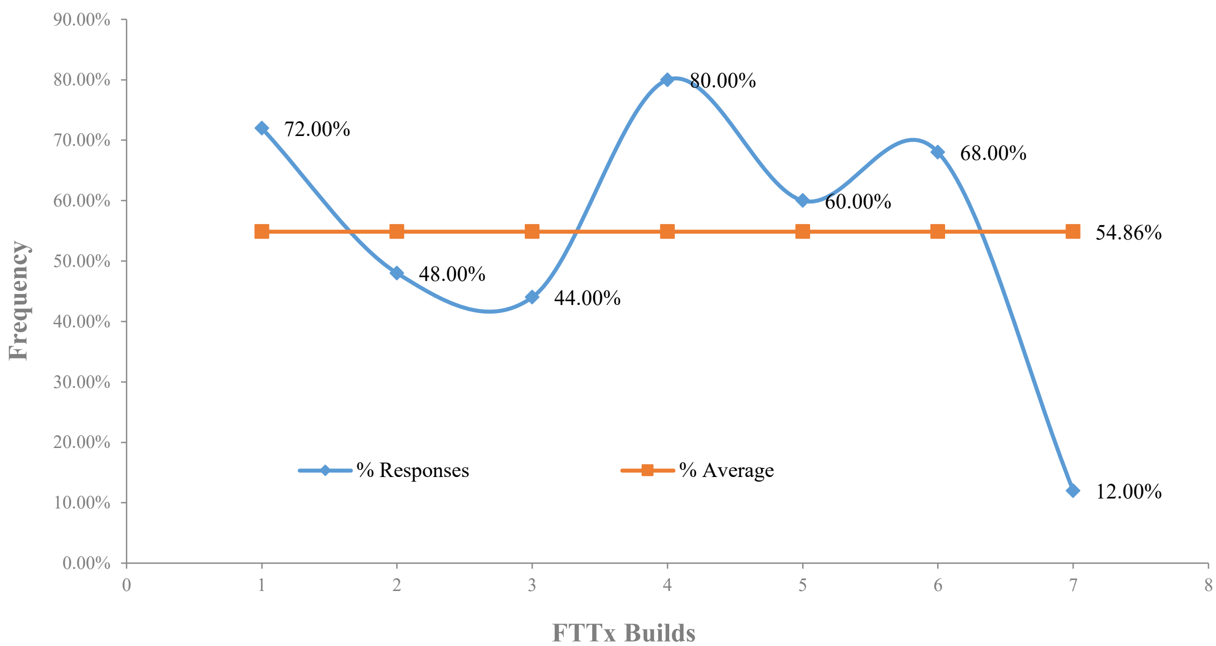


Figure 5. Type of builds

80% of the respondents classified their involvement in Fibre to the Building (FTTB) build (Fibre-optic cable installation where the fibre cable goes to a point on a shared property and other cabling provides the connection to single units, offices or other spaces MDU / MTU). However, over all with an average of 54.86% respondents classified their organizations involvement in multiple builds i.e.;

- Fibre to the Premises/Home (FTTP/H): Fibre optic cable that runs directly from an Internet Service Provider (ISP) to a home or business location.
- Fibre to the Curb (FTTC): Fibre optic cable that runs directly from an Internet Service Provider (ISP) to a pole or box that houses the mounted communications device.
- Fibre to the Node (FTTN): Installation of optical fibre to a junction box (node) in a neighborhood that serves a few hundred customers within a radius of about a mile. The connections from the node to the customer premises often uses DSL where users get a high speed bandwidth connection over existing telephone wires or coaxial cable from the cable company.
- Last Mile Connection: The final stretch of cable that comes into the house and connects the services. The main fibre line runs into the neighborhood and then splits off into individual "drop lines" that run into homes.
- Backhaul Infrastructure: Fibre optic cables used in the transportation of aggregate communication signals from base stations to the core network (e.g. as in a 5G network).

5.4.2.3 Frequency of co-deployment of fibre optic cables:

Infrastructure networks are growing in complexity resulting in coordination issues due to the construction, maintenance and operations of one network affecting the others utility networks along highways, railways and waterways at the surface; subways, pipelines and cables below the surface; communication lines and electrical lines above the surface; and wireless communications systems (Transport Association of canada, 2013). Respondents were asked to identify the frequency of co-deployment or deployment within a shared service corridor. With a majority of 66.67% & 62.50%, responses indicated the use shared utility service corridor along highways or railway routes and within the right of way and along existing power poles owned by others respectively.

5.4.2.4 Benefits of co-deployment/co-habitation of fibre-optic cables:

Individual municipalities have local laws and regulations different from those applicable throughout the province, road authorities hinge on federal and provincial laws and regulations. Further, "Government of Alberta – Economic Development and Trade" concluded in a study that steps can be taken to either mitigate costs over the long term, or strategically deploy and develop infrastructure assets that support the solutions, which will meet future as well as current needs (Government of Alberta, 2017).

17 out of the 23 (majority of 73.91%) of respondents thought co-deployment translates into improved efficiency via reduced project cost, faster deployment through "dig once, use many times" opportunities. 60.87% respondents selected the followings benefits:

- Economic benefits for projects (e.g., overall reduction in cost of transport, information and communications technology (ICT) infrastructure deployment).
- Reduction in civil construction costs
- Minimum disruption of transport services by different utilities, including telecom, power etc.

5.4.2.5 Frequency of various fibre optic cable deployment methods:

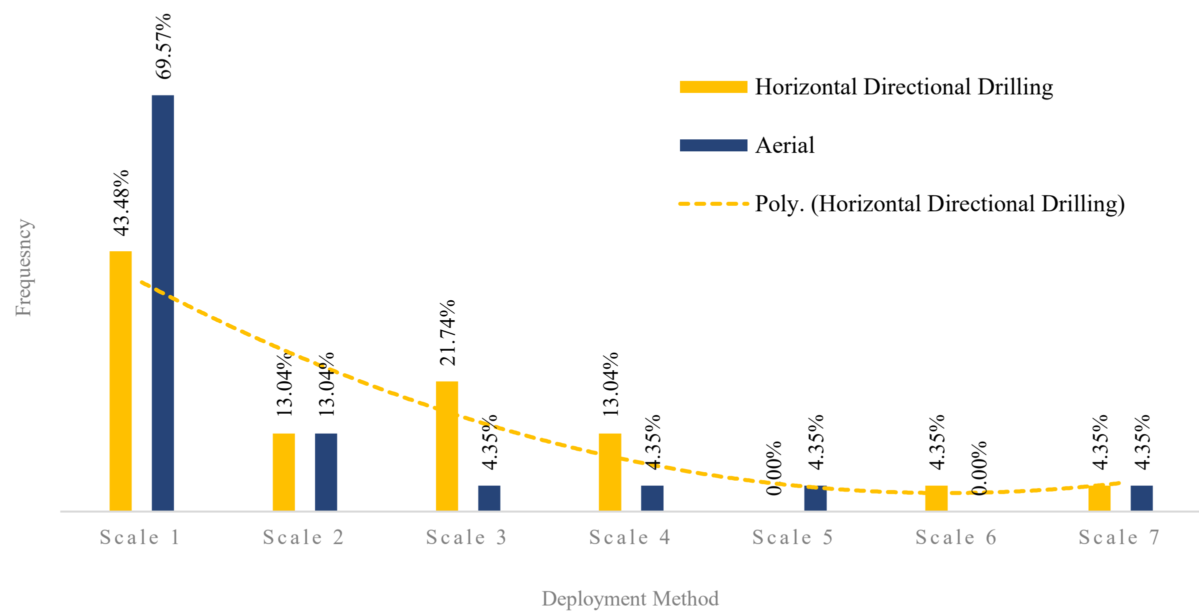


Figure 6. Most common deployment methods

16 out of the 24 respondents selected aerial deployment at 69.57% as the most common fibre optic cable deployment methods used by their organization. 10 out of 24 respondents selected HDD deployment at 43.48% as the most common fibre optic cable deployment methods used by their organization. Different deployment techniques are available for fibre optic expansion with their own benefits and drawbacks. The most common installation techniques include installation in trenched installation (open cut) and installation by trenchless methods such as horizontal directional drilling (HDD). It is important to gain an understanding of the condition of how the fibre optic network industry is fairing with the multitude of stakeholder expectations, right-of-way regulations and the available installation codes. The American Society for Testing Materials (ASTM) publish two documents which adequately cover installation of thermoplastic pipes for HDD and trenched installations as follows:

- ASTM F-1962 – Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings.
- ASTM D-2321 - Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.

5.4.2.6 Frequency of trenchless construction methods:

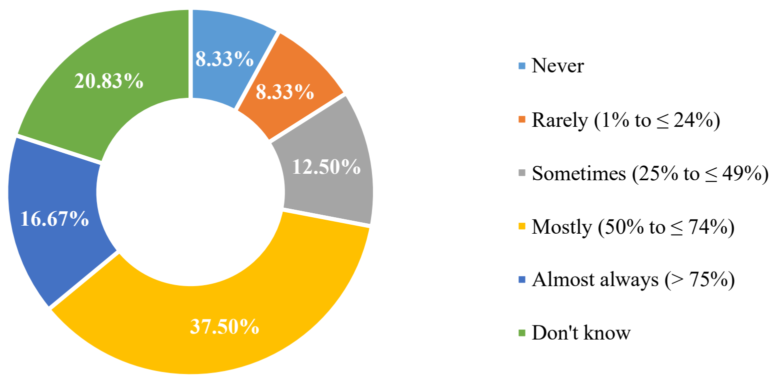


Figure 7. Trenchless methods frequency

The current edition of CSA C22.3 No.7 (Underground Systems) does not include the reduction of the minimum depth for a micro-duct to be 300 mm (12 inches). However, the Technical Committee of CSA included mircro trenching in Annex F (Informative section), which generally uses a reduced depth of cover and therefore the use of micro trenching technology can be considered within the context of Clause 1.6 of CSA C22.3 No.7, which does not prohibit the use of new technology arising out of continuing advancements in the field provided that engineering representatives can demonstrate the safety and suitability of these alternatives. This relatively new construction method is currently being implemented in a small number of telecommunications projects in Canada. The whole construction engineering sector is also seeking for advancement, efficient and productive ways to improve its output quantitatively and qualitatively. 37.50% respondents indicated that out of the fibre optic deployment projects over the last five years executed by their organization were "Mostly (range 50% to ≤ 74%)" completed using trenchless construction method.

5.4.2.7 Top factors that affect choice of deployment technique:

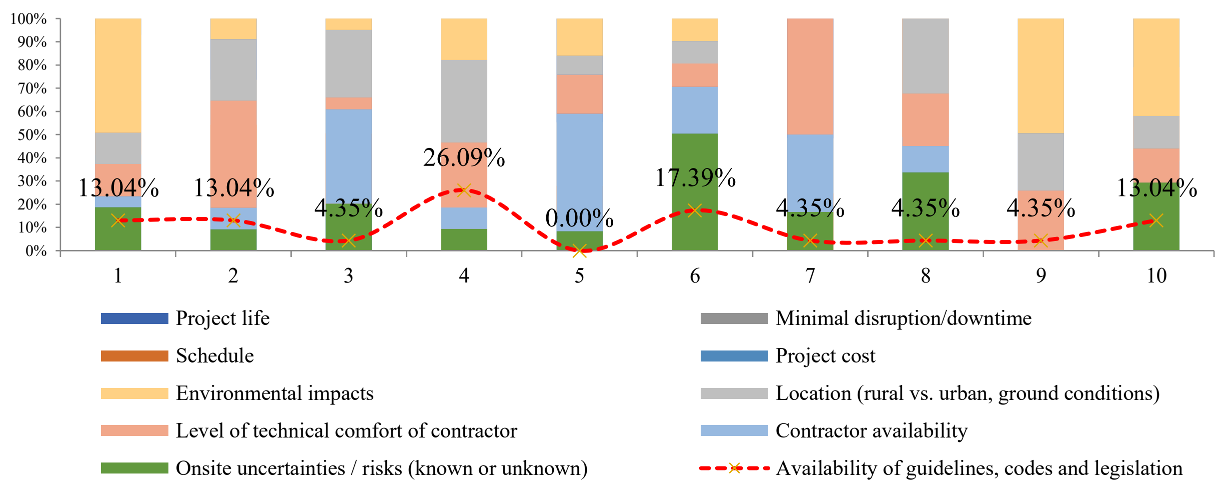


Figure 8. Choice of deployment technique (10-point scale)

Another vital parameter in the deployment technique section is the factors that affect the choice of fibre optic cable deployment or replacement method. The respondents were asked to rank the choices in order of their importance (10-point scale; 1 = Most Important, 10 = Least Important). Project cost and environmental impacts ranked the highest score on the importance scale with 54.17% and 47.83% respectively hitting the top box. Schedule and minimal disruption/downtime scored with 30.43% and 37.50% respectively hitting the top box. Availability of guidelines, codes and legislation and onsite uncertainties / risks (known or unknown) secured 13.04% and 18.18% top box hits respectively. The following factors should be considered at the site assessment phase:

● Utility crossing: A mainline crossing will almost invariably require a trenchless installation, whereas an infrequently used secondary spur or siding may be permitted to be open cut. In general, however, the preferred method of any railway crossing will be a trenchless installation.

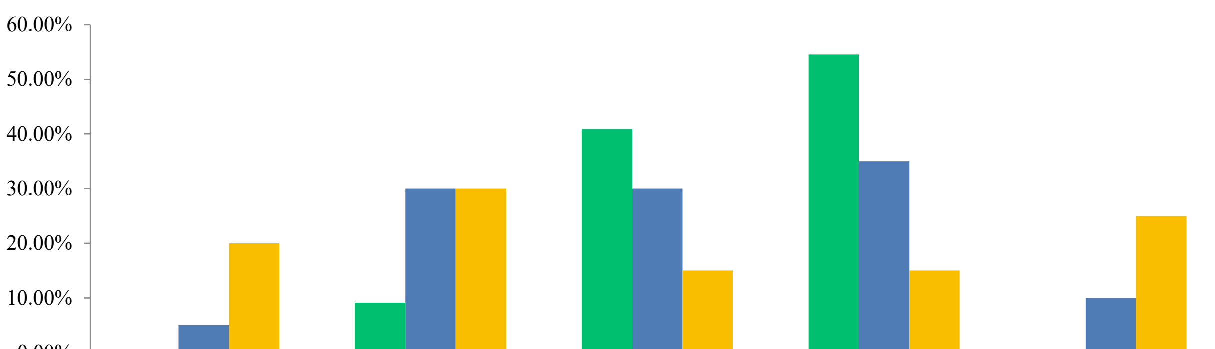
● Network layout: Is there anything unique about the site layout that would preclude or increase the complexity associated with either trenchless or open cut installation techniques?

● Soil type: The type of native soil will have an impact on construction methods. Most fine grained soils (clays, silts), medium dense sands and some gravels are usually suitable for trenchless installations such as HDD. Very loose or very dense sands and gravels, or non-homogenous soils that contain large rocks and cobbles may not be suitable for installations such as HDD.

5.4.3 Section 2B - Deployment Costs.

Costs associated with the deployment of fibre optic cable for fixed broadband access infrastructure.

5.4.3.1 Capital expenditure related to civil construction for access.

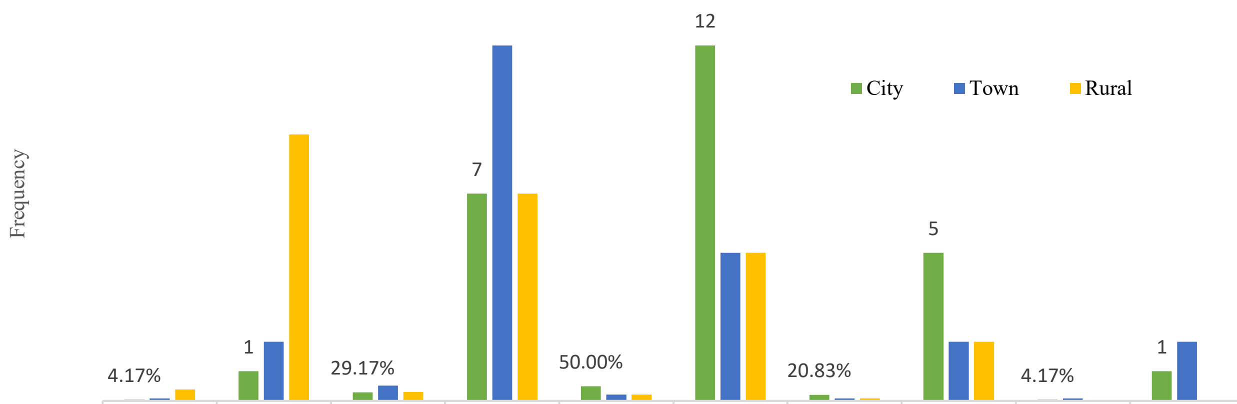


	0% to 20%	21% to 40%	41% to 60 %	61% to 80%	81% to 100%
City	0.00%	9.09%	40.91%	54.55%	0.00%
Town	5.00%	30.00%	30.00%	35.00%	10.00%
Rural	20.00%	30.00%	15.00%	15.00%	25.00%

Figure 9. Allocation of civil costs

Respondents were asked to allocate an estimated percentage of Capex costs related to civil construction for access network, including civil engineering design and permits. They were further asked to exclude costs related to customer premise equipment, passive optical network components (e.g. optical splitters to route signals) and active optical network components (e.g. router to direct signals). According to 55% of the respondents, the civil costs contribute 61% to 80% of the fibre access network while only 9% of the respondents estimate the cost of civil work to be 21% to 40% of the fibre access costs of their urban projects.

5.4.3.2 Cost savings with the reuse of existing infrastructure.



	0% to 20%		21% to 40%		41% to 60 %		61% to 80%		81% to 100%	
City	4.17%	1	29.17%	7	50.00%	12	20.83%	5	4.17%	1
Town	8.70%	2	52.17%	12	21.74%	5	8.70%	2	8.70%	2
Rural	39.13%	9	30.43%	7	21.74%	5	8.70%	2	0.00%	0

Figure 10. Co-deployment – Capital expenditure

50% of the respondents agreed that a 41% to 60% cost savings can be achieved in case of fibre deployment with the reuse of existing infrastructure (open reach ducts and poles) is carried out within an urban context. Further, 52.17% attributed 21% to 40% in towns and 39.13% attributed 0% - 20% within rural setup. An important factor affecting the access to public rights of way is the financial cost of associated with of rights of way. Telecom Decision CRTC 2001-23, 48 issued on

January 2001, granting Ledcor access to municipal rights of way, the CRTC ruled that Vancouver was entitled to recover causal costs only, such as plan review and inspection fees, relocation costs, pavement restoration and lost productivity, but it was not entitled to collect fees for the right to use those rights of way (economic rent). The CRTC stated in its reasons that, while its decision was based on the particular facts of the case, the causal costs in principle would assist municipalities and carriers in negotiating the terms on which municipal consent would be given for carriers to construct, maintain and operate transmission lines on municipal property. The decision was appealed to the Federal Court of Appeal which upheld the CRTC ruling and in 2003 the Supreme Court of Canada refused to hear a federation of Canadian Municipalities appeal.

5.4.3.3 Capital Expenditure associated with permits (Right-of-way, wayleaves, street work)

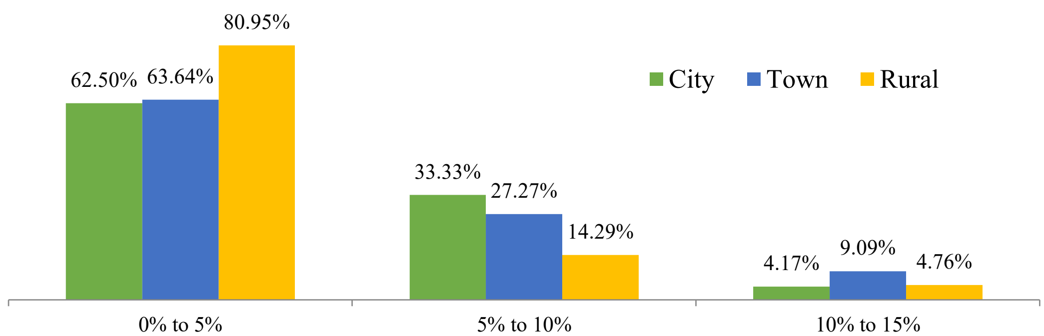


Figure 11. Right-of-way & Permits – Capital Expenditure

The trenchless deployment literature review analysis revealed that 8 out of the 42 entities claim micro trenching improves project timelines and saves the overall project cost while the remaining 34 entities provided a generic statement. Further, based on the project experiences of the survey respondents, 62.50% allocated between 0% to 5% Capex costs used in obtaining right-of-way, wayleaves, street work permissions and other permits within urban setup while 63.64% and 80.95% of the respondents allocated between 0% to 5% project costs within the towns and rural setup respectively.

5.4.3.4 Best practices to minimize deployment costs and increase Return on Investment

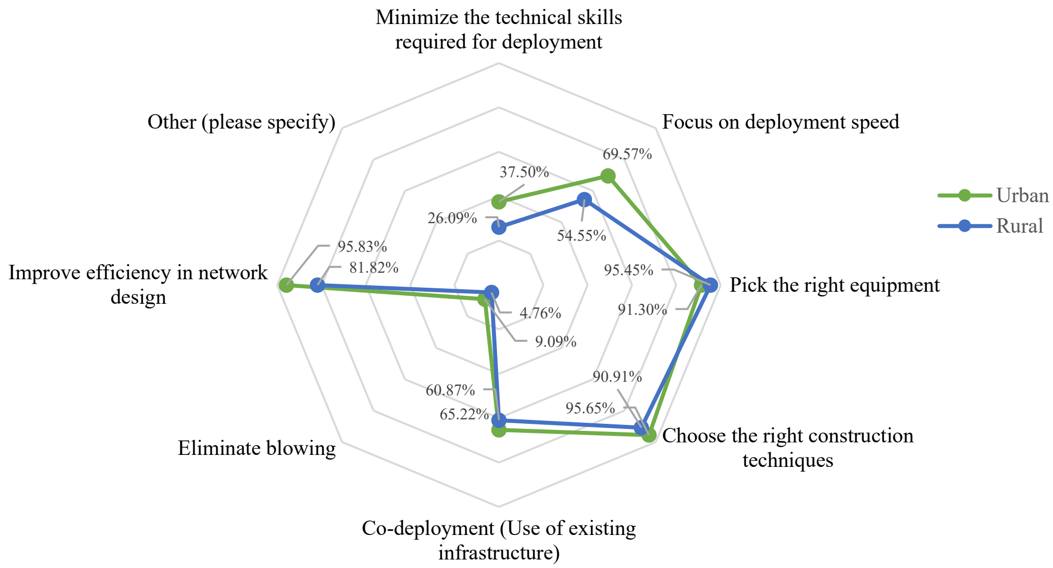


Figure 12. Best practices

Implementation of best practices such as Dig Once, time bound permits, subsidized fees & charges, project based incentives and uniformity of policy remain critical in the deployment of fibre based broadband infrastructure. Within the context of deploying fibre and in particular FTTx installations, respondents were asked to select strategies that they thought were best to minimize deployment costs and thus increase return on investment (ROI).

An average of 94.26% respondents selected the following strategies:

- Choose the right construction techniques
- Pick the right equipment
- Improve efficiency in network design

Further an average of 57.43% respondents selected the following strategies:

- Minimize the technical skills required for deployment
- Focus on deployment speed
- Co-deployment (Use of existing infrastructure)

5.4.4 Section 3 - Codes, Regulations and Standards.

Available codes, guidelines and legislation related to end-to-end fibre optic cable installation in Canada.

5.4.4.1 Availability of generic guidelines, codes and legislation:

23 out of the total 27 respondents confirmed that there are some generic guidelines, codes and legislation related to fibre optic cable deployment mandated by the federal, provincial/state or municipal jurisdictions applicable to the projects that their organization undertook. 4 of the remaining respondents skipped this question.

5.4.4.2 Availability of guidelines, codes and legislation in relation to deployment methods

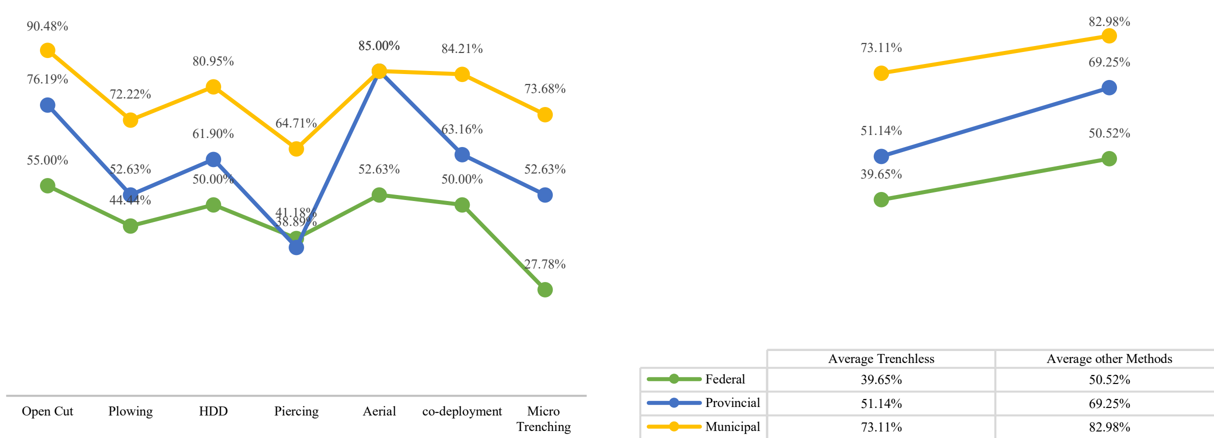
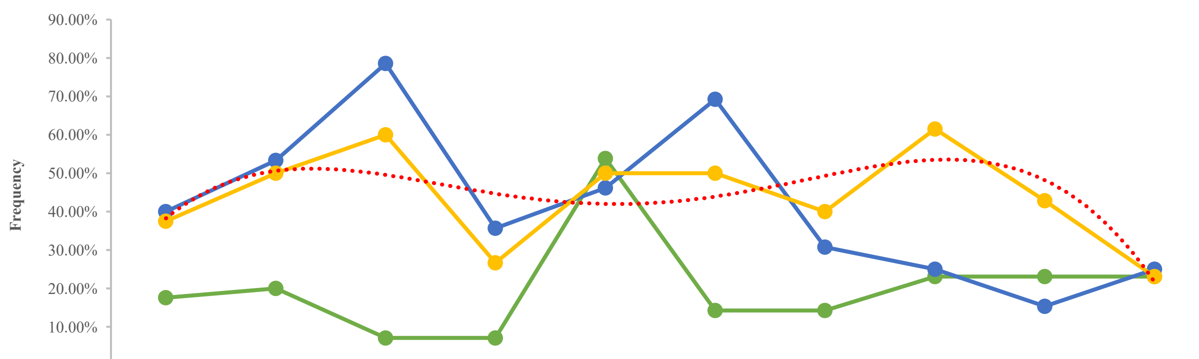


Figure 13. Availability of guidelines, codes and legislation - I

With an option to select multiple options of trenchless and traditional deployment methods against the availability of specific guidelines, codes or regulations mandated by the federal, provincial and municipal jurisdiction of undertaken project(s), an average of 39.69%, 52.14% & 73.11% of respondents identified the availability of guidelines associated with trenchless methods (Microtrenching, HDD, Piercing, etc.) at a Federal, Provincial and Municipal level respectively. Another set of variable with an average of 50.52%,69.25 and 82.98% of respondents identified the availability of guidelines associated with other methods (Aerial, Open trench, Co-deployment, Plowing, etc.) codes at a Federal, Provincial and Municipal level respectively. Availability of guidelines, codes and legislations against identified construction aspects.

Respondents were asked to select the available guidelines, codes and regulations against identified construction facets in relation to specific deployment methods mandated by the federal, provincial and municipal levels. In Alberta, the regulations for service trench and backfill construction standards as they relate to underground conduit installations are based on codes:

- The Alberta Building Code 2006
- The Canadian Electrical Code 2009
- The CSA C22.3 No.7 Underground Standard 2010



	Right of way	Locating and marking	Existing underground utilities	Surface investigation	OHS considerations	Equipment usage	Traffic control	Dimensions & tolerance zone	Engineering design and selection considerations	Testing and commissioning
Federal	17.65%	20.00%	7.14%	7.14%	53.85%	14.29%	14.29%	23.08%	23.08%	23.08%
Provincial	40.00%	53.33%	78.57%	35.71%	46.15%	69.23%	30.77%	25.00%	15.38%	25.00%
Municipal	37.50%	50.00%	60.00%	26.67%	50.00%	50.00%	40.00%	61.54%	42.86%	23.08%

Deployment Facets

Figure 14. Availability of guidelines, codes and legislation -II

- Out of the listed traditional and trenchless methods of fibre cable deployment, 63.59%, 24.09% and 27.62% of respondents noted the non-availability of specific and/or relevant guidelines, codes and regulations at federal, provincial and municipal level respectively.
- Respondents at an average of 19.91%, 39.62% & 43.65%, selected HDD method with the highest ranking comprising of right of way, location & marking, OHS considerations, dimensions, engineering design, testing and commissioning, etc. at federal, provincial and municipal level respectively.

5.4.4.3 Organizational practice in case of no availability of Municipal codes.

City of Toronto recommends the maximum width of the grooves not exceed 25 mm in both longitudinal and transverse directions while the depth of the grooves not exceed the depth of the asphalt layer in composite pavements, meaning the grooves must not penetrate the concrete base to any extent. City of Vancouver deems micro trenching as a non-conventional construction. While recommend provisions to protect underground utilities and work around surface inlaid fibre, by providing that if an underground utility gives adequate notice (three working days), the company installing surface inlaid fibre would protect, move or remove their fibre or live with the consequences of damage. Further, City of Edmonton requires an authorization of utility and monitoring well installations within public road right of way by external agencies and private utilities must first enter into an agreement with the City of Edmonton. The agreement usually takes the form of a Right of Way Consent & Access Agreement or a Franchise Agreement. A standard condition of the agreements is that all utility installations require City approval in the form of a Utility Line Assignment (ULA) Permit. The Contractor is required to comply with all right-of-way crossings requirements for all utilities. Separate 50 mm conduits are to be installed for power, detection, telecommunication and control. All conduits which are installed from the controller cabinet to the pole must be 50 mm. Conduit entrances into pull boxes must be installed such that conduit designated for communication is capable of accommodating a minimum of 23 cm bend radius and a minimum of 30 cm clearance from the top of the cable bend to the top of the pull box. In the event of unavailability of municipal/local guidelines, codes or regulations related to the selected deployment method, 100% respondents selected the reference to best practices option. Further 66.67% and 33.33% respondents selected the review of contractor/subcontractor proposal and reference to the published case studies of similar projects respectively.

5.5 Conclusion

While the literature analysis complements this industry specific survey questionnaire, the data gathered through this study is not comprehensive and rather limited to the information obtained from the 27 respondents with their project specific experiences predominantly from the provinces of Alberta, British Columbia, Ontario and Quebec. Some of the discrepancies and skewed output in the survey is caused by the insufficient information provided by participants. The output can only be improved through more data collection in the future across the country to make it more reliable. Other minor data collection errors are caused due to the nature of the survey, as the survey gears mostly using multiple choice question in order to save answering time, where places such as the total does not add up to 100% was due to the selection range. The underlying scope of the survey was to determine if deployment methods of fiber optic cable were specifically addressed by any municipal policy. The respondents did not report any specific policy for accommodating fibre installation in the right of way guidelines or the civil works codes. This implies that the approach in coordinating the interface between utility companies varies from each project jurisdiction. Most provinces coordinate the fibre installation on a project basis and only few supplements are available with generic guidelines. The limitation of coordination with ad hoc methods (i.e., projects are assessed on a case-by-case basis) prevents working on broad policy issues that lead to irregularities in approaches and standards. Therefore, the effectiveness and enforcement dependent on the negotiations and review of contractor/subcontractor proposal. In addition, there is a broad consensus to refer to the industry best practices in the event of unavailability of municipal guidelines, codes or regulations related to the selected deployment method.

Chapter 6 : Overall Research Conclusion

This research evaluated the extent to which Federal, Provincial and Municipal authorities codify fibre deployment in Canada. At an average of 39.69%, 52.14% & 73.11% of respondents identifying the availability of guidelines associated with trenchless methods (Micro-trenching, HDD, Piercing, etc.) at a Federal, Provincial and Municipal levels respectively. At Provincial and Municipal levels apart from their own permit requirements they often refer the contractors to secure ROW permits from the relevant Gas Pipeline or Railway regulator. In addition, all the regulators recommend but do not enforce a call before you dig program managed by CCGA. CCGA promotes dig before you call policy, however it is the responsibility of the contractors to secure the underground utilities. Local Municipalities (e.g City of Calgary) refers to the Building Code requirements for entrance cables laid down by the Canadian Electrical Code under section 60. In addition, Standard documents from CSA Standard are referenced by regulatory agencies (e.g C22.3, No. 7) related to installations of conduit. While there are several fibre deployment initiatives in place across Canada, this research demonstrates that local jurisdictions have little or no specific codes and guidelines available to accelerate the deployment. Although the municipalities may have no legal authorities both to make ducts of other utilities available to communications entities (for their network and to prevent access to public rights of way), however it is recognized that municipalities have an important role to play in coordination between all entities seeking to occupy and use municipal rights of way, especially the larger municipalities. Further, there is no system of safeguards ensuring a deadline to receive public rights of way permits, while as these timelines are critical across all infrastructure providers for seamless and time-bound broadband infrastructure builds. Specific standards addressing GIS mapping, depth of fibre deployment below the ground, duct/conduit size, inner duct installation standards, method of installation, route definition and bends, and usage of defined tools and materials are critical for sustainable fibre infrastructure deployment. Lack of legal requirement for sharing of the duct space was observed in spite of CRTC noting the importance of joint planning. The co-ordination of all parties seeking to occupy and use municipal rights-of-way, especially the urban municipalities with dense downtown forms a strong use case for the joint planning including the fibre optic service providers. Based on the literature analysis and the online survey results, it can be concluded that lack of province wide code adoption of regulatory guidelines and policies on fibre deployment and management pose a major threat to fibre optics deployment in the urban as well as rural and remote communities of Canada.

6.1 Recommendations - Fiber Build Strategies

There are gaps in regulatory frameworks (municipal, provincial and federal levels) related to fibre deployment, particularly for newer technologies. Following are some of the academic recommendations:

1. No specific guidelines associated with Micro-trenching are reported. Only 19% of the entities claim improvements in project time & Cost when using trenchless deployment methods. Further Municipal standards addressing depth of fibre below various ground types, duct/conduit size, duct installation standards, method of installation, routing and bends standards, and usage of defined tools and materials is required to address the gap which in turn will encourage the adoption of the Micro trenching method as a fibre deployment. A fiber optic installation manual that is referenced based on municipal codes, guidelines and industry best practices will provide essential information and guidance on planning the fibre network

including the choice of installation method. This manual must include precise information on a variety of topics including joint trenching, trenchless techniques, planning, excavation and backfilling, traffic control, and as-builds.

2. The respondents did not report any specific policy for accommodating fibre installation in the right of way guidelines of regulators. Lack of coordination & standardization between utility companies while local jurisdictions have little or no specific codes and guidelines available to accelerate the deployment. To ensure a sustainable, scalable and reliable network asset that ensure network synergies across the country, it is critical to adopt global standards and customize them for infrastructure rollouts. These standards would include depth of trenching, size of ducts depending on the areas and type of cabling there is, deployment methods, etc. Additionally, setting standards enables the broadband infrastructure process to become sustainable from an environmental perspective. The life and quality of the fibre optic network is critically dependent on the physical network design and installation practices. Specific standards associated with the deployment of fibre and scalable network design will optimize the network sizing and installation of the network. This also needs program management expertise to ensure longer asset life. Local Municipalities must centralize coordination between all regulators when seeking rights of way for fibre build. Municipal investments in improvements towards utility as-built and a universal co-deployment mandate and its enforcement. An initiative spearheaded by local municipalities to invest in utility as-builts and updating of all utility records in the right-of-way and vicinity of their jurisdiction can improve the record accuracy and hence reduce the overall cycle time. Furthermore, a dynamic and iterative online repository is recommended which serves as a single point of information for

all stakeholders to access the latest information on relevant codes, regulations and best practices of end to end fibre build.

3. All regulators have an ad hoc method in place to secure permits, preventing work on broad policy issues leading to irregularities in approaches as well as standards. Strick SLA's around rights of way permit cycle time across regulators. In addition, an online repository which serves as a single point of information for all stakeholders to access the latest information on relevant codes, regulations and best practices around end to end fibre deployment. This dynamic repository may include:

   3.1. Material and dimensions of conduit or duct that would be used for the purpose of fibre installation. Option of gaps in the placement of fibre, in the case of conduit based or direct underground deployment.

   3.2. Specific standards spelled out to ensure that the fibre optic cable is not put through stresses in the process of laying and regulations to address the traceability of the installed cable during the maintenance stage, the entire installation parameters.

   3.3. Specific tools and material need to be used to ensure that fiber laying and commissioning is incident free and long lasting. In addition, standards to address material requirement, design and constructional requirements, installation details and methods of tests as needed.

4. Deployment with varying soil types, unique site layouts in particular brownfield, planning fiber route and adhering to the planned routes become challenging. Right of way acquisition to lay utilities like fiber optic cables is extremely time-consuming since the process involves the acquisition of a license to lay fiber optics cable along the public street which has direct

consequences in the implementation timelines. Local Municipalities must encourage the real estate developers to install communications conduit along their RoW as part of the development benefit/amenity for the community. Municipalities and other regulators, by offering an incentive along with simplified the permitting process can attract developers to install conduit for the benefit of their organization. Further, regulators must advocate and encourage the adoption of a Dig Once Policy by mandating and enforcement of the installation a communications duct and vaults along with other utility upgrades. This policy has many advantages, including cost saving and minimization of impact to roadways. There will need to be robust coordination between multiple stakeholders to ensure proper implementation through advocating and planning. Local Municipalities and Provincial regulators can significantly lower the civil costs through joint builds or cost sharing. At the same time the incumbent service providers can also benefit through leasing the ducts owned by other utilities owners and minimizing the overall capital cost.

6.2 Future Work

The policies, guidelines, standards, specifications and regulations vary from one province to another. Fibre optic cables are currently being be installed in accordance with each applicable authority's guidelines. These guidelines and standards should be updated from time to time based on the advancement of the construction methodology in order to achieve an ideal state of reducing potential overlap and delay to in network route planning and installation of fibre infrastructures. It is observed that most of the fibre deployments piggy-back on codes and regulations that apply other underground utilities, including electric power, legacy copper services, water, gas, sewer and similar vital infrastructure. Due to the lack of uniformity in the guidelines and lack of specific fibre deployment codification, the risk and responsibility of construction and its associated works is completely transferred to the fibre service provider.

In this research, a high level understanding is acquired on how regulatory guidelines can influence efficiency of fibre deployment. Future work could examine the role of codification & policy against the outcomes of the fibre deployment across multiple cities Canada. The current survey and the collected data analysis forms a transition to the next level in improving a future survey that will be sent out to collect more comprehensive data from a broader range of municipalities across Canada. The subsequent quantitative analyses will be carried out across municipal jurisdictions both with and without specific guidelines associated with fibre deployment in correlation with the construction methodologies. Further, understanding the fibre footprint including its cost, productivity, etc. could be reflective of the project performance indicator and the resulting delta cab be helpful in coming up with the detailed codification requirements.

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Appendix – I

Questionnaire*: Current State Assessment of Guidelines, Codes and Legislation for Fibre Optic Cable Deployment (Pro00107518).*

Assessment of Current State of Guidelines, Codes and Legislation for Fiber Optic Cable Deployment

1. **Welcome**

You have been selected to respond to a survey developed by CETT researchers at the University of Alberta titled *Assessment of Current State of Guidelines, Codes and Legislation for Fiber Optic Cable Deployment*. The primary objectives of this study are to

1. Identify and summarize the preparations and precautions required before fiber optic cable installation, including identification of existing underground utilities such as buried cables, pipes etc.
2. Identify and analyze the codes, guidelines and legislations for:

- Securing the proper right-of-way permits
- Determining recommended soil conditions
- Determining the appropriate installation dimensions (width, depth) for trench Identifying the
- type of fibre optic cable and associated equipment
- Determining the recommended reinstatement product for after fiber optic cable deployment

Background
This survey forms part of an overall research project under the NSERC Associate Industrial Research Chair in Underground Trenchless focused on investigating the optimal installation method for the quick and effective distribution of communication infrastructure telecommunications. The survey also aims to gain an overall perspective on the current state of fiber optic cable deployment guidelines, codes and legislation across Canada. The survey contains a total of 29 questions over 11 pages and is expected to take approximately 5-10 minutes to complete. Your participation and feedback regarding the survey is appreciated.

The survey is organized as follows:

Section 1: Demographics
Segmentation based on geographical location of operations, market segmentation, industry vertical etc.
Section 2A: Deployment Techniques
Techniques associated with the installation of fibre optic cables.
Section 2B: Deployment Costs
Costs associated with the deployment of fibre optic cable for fixed broadband access infrastructure. Section 3:
Codes, Regulations and Standards
Available codes, guidelines and legislation related to end-to-end fiber optic cable installation in Canada.

Assessment of Current State of Guidelines, Codes and Legislation for Fiber Optic Cable Deployment

2. **Introduction (1/3)**

Principal Investigator
Dr. Alireza Bayat
Professor, Department of Civil and Environmental Engineering, University of Alberta Director,
Consortium of Engineered Trenchless Technologies
Edmonton, AB
(780) 492-5112

Co-Investigator
Mudasir Mir
Graduate Student, Department of Civil and Environmental Engineering, University of Alberta
Edmonton, AB T6G 1H9
(780) 690-8007

Study Coordinator
Lana Gutwin
Research Coordinator, Department of Civil and Environmental Engineering, University of Alberta Consortium for Engineered Trenchless Technologies
Room 7-389 Donadeo Innovation Centre for Engineering 9211
116 Street NW
Edmonton, AB T6G 1H9 (780)
492-5106

Invitation to Participate

You are being invited to participate in this research study (Assessment of Current State of Guidelines, Codes and Legislation for Fiber Optic Cable Deployment) because of your knowledge and/or involvement in decision-making related to fibre optic cable deployment.

3. **Introduction (2/3)**

Benefits

By completing this survey, you will assist researchers in understanding the current state of guidelines, codes and legislation across Canada related to fibre optic cable deployment. This will allow researchers to gain a comprehensive understanding of the codes, guidelines and legislations that are applicable in different jurisdictions and how they compare across jurisdictions, and also be beneficial for governing bodies (e.g. municipalities, provinces) in developing legislative frameworks for these emerging technologies.

There is no monetary compensation for participating in this research, and there is no direct benefit to participants. However, on completing the survey and providing your contact information, you can indicate if you would like to be provided with a summary of the survey results (in publication form). This summary may be a benefit to you and/or your company.

Risks

There are no known or anticipated risks to respondents resulting from participation in this survey.

Confidentiality and Anonymity

The information that you will share will remain strictly confidential and will be used solely for the purposes of this research. The only people who will have access to the research data are the Principal Investigator, Co-Investigator, and Research Coordinator. Aggregated data and your answers to open- ended questions may be used in presentations and publications but neither you (nor your organization) will be identified. To minimize the risk of security breaches and to help ensure your confidentiality, we recommend that you use standard safety measures such as signing out of your account, closing your browser and locking your screen or device when you have completed the survey. Please note that the online survey tool used for data collection is housed on servers located in the continental US and that the data held on such servers is subject to US privacy legislation.

Results will be published in pooled (aggregate) format. No information that directly identifies you or your organization will be published; however, even if not named explicitly, it is possible that a responding organization could be identified through context or due to the nature or size of the sample.

Providing your contact information is completely voluntary: if provided, this information will only be accessible to the Research Coordinator. Any personally identifying information (e.g. name, address, email address) will be stripped from the data before data analysis.

Data Storage

Electronic copies of survey responses will be encrypted and stored on a password-protected computer in the Department of Civil and Environmental Engineering at the University of Alberta.

Compensation / Reimbursement

There is no compensation for taking part in this research study.

Assessment of Current State of Guidelines, Codes and Legislation for Fiber Optic Cable Deployment

4. **Introduction (3/3)**

Voluntary Participation

You are under no obligation to participate and if you choose to participate, you may skip any questions that you do not want to answer. If you choose to withdraw midway through the electronic survey, simply close the link and no responses will be submitted. If you would like to withdraw your submission after completing the survey, you can do so within 30 days by sending a written request to gutwin@ualberta.ca (Lana Gutwin, Research Coordinator) and identifying the name of the organization indicated in the survey response. No explanation is required to withdraw your submission. After 30 days, it is possible that results may have been analyzed, written up and/or presented and it may not be possible to withdraw your survey responses. Please note that if you skipped all the questions that would allow us to identify your individual survey response, then it may not be possible to withdraw the data you provided.

Information about the Study Results

The aggregate results of this survey will be published. By indicating your preference on the survey and providing your contact information (name and email address) you can be provided with a copy of the survey results in publication form when they are published.

Questions

If you have any questions or require more information about the study itself, you may contact the researcher(s) using the contact information included above. The plan for this study has been reviewed by a Research Ethics Board at the University of Alberta. If you have questions about your rights as a research participant or how the research is being conducted, you may contact the Research Ethics Office at (780) 492-2615. This office is independent of the researchers. Please reference the survey "Assessment of Current State of Guidelines, Codes and Legislation for Fiber Optic Cable Deployment".

Please print a copy of this form for your records.

Assessment of Current State of Guidelines, Codes and Legislation for Fiber Optic Cable Deployment

5. **Consent**

Please note that completion and submission of the survey indicates your consent to participate.

* 1.

I have read the survey information and the research study has been explained to me. I have been given an opportunity to ask questions about the survey. I have been told who to contact if I have any additional questions or if I would like to withdraw my responses (up to 30 days after submission of the survey). I understand that by completing and submitting this survey, I have given consent for the data I have provided to be used for the purposes of this study, as described in the information provided.

For a pdf copy of the survey or if you have any questions, please email the Study Coordinator at gutwin@ualberta.ca

6. **Section 1: Demographics**

This section is intended to give an overview of the respondents based on the geographical locations of operation and high level data related to the populations being served, market segmentation and industry verticals, etc.

* 2. Please select the applicable geographic location(s) of fibre optic cable installations that your organization has been involved in.

- [ ] Africa
- [ ] Antarctica
- [ ] Asia
- [ ] Oceania (Australia, New Zealand, etc.)
- [ ] Europe
- [ ] USA
- [ ] United Kingdom
- [ ] Canada
- [ ] Mexico
- [ ] Central America
- [ ] South America
- [ ] Middle East
- [ ] West Indies

3. If your selection above was Canada, please select the applicable provinces and/or territories where your organization operates.

Not Applicable

Alberta

British Columbia

Ontario

Manitoba

New Brunswick

Newfoundland and Labrador

Nova Scotia

Quebec

Saskatchewan

Northwest Territories

Iqaluit

Yukon

4. How would you classify your organization?

- Infrastructure or Utility Owner
- Service Provider
- Technology provider
- Municipality
- County / Region
- Consultant
- Contractor
- Equipment Manufacturer / Supplier
- Other (please specify)

5. If you are an infrastructure or utility owner, how would you categorize your organization? (Please select all that apply)

- Federal Government
- Provincial Government
- Municipality
- Gas
- Telecommunication
- Please specify
- Hydro
- Transportation Agency
- Developer/Land Developer
- Builder - Residential
- Builder - Commercial
- Railway
- Port
- Airports
- Contractor
- Design Consultant

6. What size of population is served by your organization?

- Small: 5,000 to 29,999 people
- Medium: 30,000 to 99,999 people
- Large: 100,000 to 399,999 people
- Very large: more than 400,000 people

7. Please indicate which area(s) you mainly deploy networks in.

- Urban (City)
- Urban (Town)
- Rural
- Both urban & rural

8. Which market segment(s) do you primarily serve?

- Residential
- Business
- Both residential & business

7. **Section 2A: Deployment Technique**

9. Please indicate whether your organization is involved in deployment of fiber optic cables directly (e.g., contractor who performs installations) or indirectly (e.g., municipality who issues permits, service provider who contracts out fibre deployment, etc.)

- ○ Direct Involvement (Contractor, etc.)
- ○ Indirect Involvement (Municipality, Service Provider, Supplier, etc.)

10. Out of the following, which deployment projects does your organization support?

- ☐ Fibre to the Premises/Home (FTTP/H): Fibre optic cable that runs directly from an Internet Service Provider (ISP) to a home or business location.
- ☐ Fibre to the Curb (FTTC): Fibre optic cable that runs directly from an Internet Service Provider (ISP) to a pole or box that houses the mounted communications device.
- ☐ Fibre to the Node (FTTN): Installation of optical fibre to a junction box (node) in a neighborhood that serves a few hundred customers within a radius of about a mile. The connections from the node to the customer premises often uses DSL where users get a high speed bandwidth connection over existing telephone wires or coaxial cable from the cable company.
- ☐ Fibre to the Building (FTTB): Fibre-optic cable installation where the fibre cable goes to a point on a shared property and other cabling provides the connection to single units, offices or other spaces.
- ☐ Last Mile Connection: The final stretch of cable that comes into the house and connects the services. The main fiber line runs into the neighborhood and then splits off into individual “drop lines” that run into homes.
- ☐ Backhaul Infrastructure: Fibre optic cables used in the transportation of aggregate communication signals from base stations to the core network (e.g. as in a 5G network).
- ☐ Other (please specify)

11. Is your organization involved in co-deployment of fibre optic cables along other infrastructure, such as roads, railway, and energy (e.g., gas, oil, or electricity) infrastructure? Please select the options that apply.

- ☐ Along highway or railway routes and within the right of way
- ☐ Along highway or railway routes but located **outside** the right of way
- ☐ Along existing power poles
- ☐ Only allowed crossing (in the transverse direction) of the route
- ☐ Directly buried and taken through pipes
- ☐ Through concrete conduits
- ☐ Not sure
- ☐ Other (please specify)

12. Based on your experience, what are the benefits of co-deployment/co-habitation of fibre-optic cables along shared infrastructure routes?

- ☐ Improved efficiency via reduced project cost, faster deployment through “dig once, use many times” opportunities
- ☐ Economic benefits for projects (e.g., overall reduction in cost of transport, information and communications technology (ICT) infrastructure deployment)
- ☐ Additional and diversified revenue earnings to utility/infrastructure agency from lease of unused bandwidth to telecom operators
- ☐ Financially beneficial only for some agencies/entities
- ☐ Financially beneficial for all (win-win)
- ☐ Enhanced sustainable development along with employment generation
- ☐ Reduction in civil construction costs
- ☐ Minimum disruption of transport services by different utilities, including telecom, power etc.
- ☐ Improved road safety
- ☐ Improved traffic management
- ☐ Enhanced sustainable development along with employment generation
- ☐ Other benefits (please specify)

13. Please rank the following fibre optic cable deployment methods used by your organization in order of frequency of use.

1 = Most Common, 7 = Least Common

Note: If factors are of equal importance, the same rating can be applied.

	Frequency
Traditional Trenching (Open Cut)	
Plowing	
Horizontal Directional Drilling	
Piercing	
Aerial	
Trenching (Micro / Mini / Nano)	
Co-deployment	

14. Of the fibre optic deployment projects executed by your organization over the last five years, how often were trenchless construction methods used?

- [ ] Never
- [ ] Rarely (1% to ≤ 24%)
- [ ] Sometimes (25% to ≤ 49%)
- [ ] Mostly (50% to ≤ 74%)
- [ ] Almost always (> 75%)
- [ ] Don't know

15. Please rank the following factors that affect the choice of utility deployment or replacement method for a specific project, in order of their importance.

1 = Most Important, 10 = Least Important

Note: If factors are of equal importance, the same rating can be applied.

Project cost	
Schedule	
Minimal disruption/downtime	
Availability of guidelines, codes and legislation	
Project life	
Onsite uncertainties / risks (known or unknown)	
Contractor availability	
Level of technical comfort of contractor	
Location (rural vs. urban, ground conditions)	
Environmental impacts	

8. **Section 2B: Deployment Costs**

Note: For the purpose of Questions 16 to 19, please note that capital expenditures (CapEx) are funds used by a company to acquire, upgrade, and maintain physical assets such as property, plants, buildings, technology, or equipment.

16. Based on your own experience, please allocate an estimated percentage of CapEx costs related to civil construction for access network, including civil engineering design and permits. Please exclude costs related to customer premise equipment, passive optical network components (e.g. optical splitters to route signals) and active optical network components (e.g. router to direct signals).

	0% to 20%	21% to 40%	41% to 60 %	61% to 80%	81% to 100%
City	☐	☐	☐	☐	☐
Town	☐	☐	☐	☐	☐
Rural	☐	☐	☐	☐	☐

17. Reuse of open reach ducts and poles could significantly reduce the costs associated with fibre deployment. Based on your experience with the reuse of existing infrastructure, how much do you think physical infrastructure access could reduce costs? Please select your estimate of the cost savings (percentage range).

	0% to 20%	21% to 40%	41% to 60 %	61% to 80%	81% to 100%
City	☐	☐	☐	☐	☐
Town	☐	☐	☐	☐	☐
Rural	☐	☐	☐	☐	☐

18. Based on your experience, what percentage of the CapEx costs of a project are used in obtaining right-of-ways, wayleaves, street work permissions and other permits?

	0% to 5%	5% to 10%	10% to 15%
City	☐	☐	☐
Town	☐	☐	☐
Rural	☐	☐	☐

19. The following question should be answered within the context of deploying fiber across your networks. Based on your experience in working with FTTx installations, what strategies are best to minimize deployment costs and thus increase return on investment?

	Urban location	Rural location
Minimize the technical skills required for deployment		
Focus on deployment speed		
Pick the right equipment		
Choose the right construction techniques		
Co-deployment (Use of existing infrastructure)		
Eliminate blowing		
Improve efficiency in network design		

Other (please specify)

9. **Section 3: Guidelines, Codes and Legislations**

* 20. Please indicate if there are any generic guidelines, codes and legislation related to fibre optic cable deployment mandated by the federal, provincial/state or municipal jurisdictions applicable to the projects your organization undertakes.

21. Within the jurisdictions that your organization undertakes projects, are there any existing guidelines, codes or regulations related to the following deployment methods? From the list below, please select all the available guidelines, codes and regulations related to your selected deployment method mandated by the federal/national, provincial/state and municipal/local jurisdiction of your project(s).

	Federal / National	Provincial / State	Municipal / Local
Traditional Trenching (Open Cut)			
Plowing			
Horizontal Directional Drilling			
Piercing			
Aerial			
co-deployment			
Trenching (Micro / Mini / Nano)			

22. From the list below, please select all the available guidelines, codes and regulations related to your selected deployment method mandated by the federal/national, provincial/state and municipal/local jurisdiction of your project.

	Federal/National	Provincial/State	Municipal/Local
Right of way			
Locating and marking			
Existing underground utilities			
Surface investigation			
OHS considerations			
Equipment usage			
Traffic control			
Shoring			
Dimensions & tolerance zone			
Engineering design and selection considerations			
Testing and commissioning			

23. Assuming that the municipal/local jurisdiction of your project does not mandate any guidelines, codes or regulations related to your selected deployment method, please select all the resources that would be used by your organization from the list below:

- [ ] Reference to best practices
- [ ] Ad hoc methods (i.e., projects are assessed on a case-by-case basis)
- [ ] Review of contractor/subcontractor proposal
- [ ] Speed of construction/build
- [ ] Published case studies of similar projects (if available)
- [ ] Other (please specify)

10. **General Information**

24. Please indicate if you would like to receive the results of the survey (in publication form).
Note: If you check yes, please provide your contact information in the next question.

- Yes
- No

25. Please provide your contact information below.
Note: You do not need to provide contact information; however, this will allow us to send you the copy of the results of the survey (in publication form).

Name

Company

Email Address

26. I give permission for study personnel to contact me for additional information related to the survey responses provided.

- Yes
- No

27. How did you hear about this survey?

28. Please provide us with any additional comments/feedback related to this survey or specific topics within the survey.

11. **Survey Complete**

Thank you for your participation in the survey *Assessment of Current State of Guidelines, Codes and Legislations for Fiber Optic Cable Deployment*. We greatly appreciate your time and look forward to sharing the results of this research.