Utilization of Trenchless Construction Methods by Canadian Municipalities

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Abstract: Trenchless technology is an emerging area of construction involving innovative methods, materials, and equipment used for the installation of new and the rehabilitation or replacement of existing underground infrastructure with minimal or no need for open cut excavation. This technology provides an alternative to traditional methods of open trenching construction, which is often associated with major disruptions to surface activities. The results of a survey of trenchless construction methods in Canada are presented in this paper. The survey, which was sent to 87 municipalities across Canada, provides an indication of current and future trends in the application of trenchless construction technologies in the municipal arena including type and frequency of technologies employed, percentage of projects that employed trenchless technologies, and contractor selection methods. The survey results indicate that trenchless technology is gaining increasing popularity among municipal engineers across Canada. The percentage of all municipal projects utilizing trenchless construction methods has grown over the past 5 years by 180% (new construction) and 270% (rehabilitation). The survey also revealed that the typical Canadian municipality spends $29.68/capita on new construction of municipal service lines and $18.21/capita on rehabilitation of existing lines.

INTRODUCTION

As we enter the 21st century, utility companies and local municipalities are faced with the tremendous task of maintaining and expanding their utility infrastructure (i.e., power, telecommunications, water mains, and sewer). Traditionally, the installation, inspection, repair, and replacement of underground utilities involves open trenching construction methods. Such operations may be proven expensive, particularly in congested urban areas. Contractors must cautiously dig while maneuvering around other utilities to achieve the required depth, which in turn slows down the operation. Additional costs are typically incurred by the need to restore the existing surfaces (i.e., sidewalks, pavement, brick paving) and repairs resulting from ground settlement. Aside from the associated high agency costs, open cut trenching operations often result in high user, or ''social,'' costs due to the disruption to traffic and adverse impact on nearby businesses (Pau et al. 1993; Boyce and Bried 1994; Thompson et al. 1994; McKim 1997).

Faced with the urgent need to rehabilitate or replace aging utility systems on the one hand, and dwindling revenues, increased environmental regulations, and increased emphasis on user costs on the other, municipalities and utility companies are beginning to seek alternative methods for repairing and replacing their underground assets. The answer may be provided in the form of trenchless construction—a family of methods, materials, and equipment that can be used for the installation of new, or the rehabilitation of existing, underground conduits with minimum or no excavation requirements.

This paper outlines the results from a survey of trenchless technology in Canadian municipalities. The survey, which was sent to 87 municipalities across Canada, provides an indication of current and future trends in the application of trenchless construction technologies in the municipal arena including type and frequency of technologies employed, percentage of projects that employed trenchless technologies, and contractor selection. For the purpose of this paper a distinction was made between new construction and rehabilitation technologies. New construction techniques include horizontal directional drilling (HDD), microtunneling (MT), pipe jacking (PJ), auger boring (AB), and pipe bursting (PB). Rehabilitation techniques cited include lining of pipe (LP), pipe scanning and evaluation (PS&E), and robotic spot repair (RSR).

RESEARCH OBJECTIVES AND METHODOLOGY

The main objectives of this research were to gain insight into the utilization of trenchless construction methods by Canadian municipalities. To achieve this objective, 87 surveys were distributed to municipalities across Canada. A copy of the survey is found in Appendix I. The sample selected represents a wide range of geographical locations, geological conditions, and population sizes. Responses were received from 53 municipalities resulting in a 61% response rate (Appendix II). Geographically, responses were received from every province and territory in Canada with the exception of Newfoundland and Prince Edward Island.

OVERVIEW OF TRENCHLESS CONSTRUCTION

The North American Society of Trenchless Technology defines trenchless construction as ''a family of methods, materials, and equipment capable of being used for the installation of new or replacement or rehabilitation of existing underground infrastructure with minimal disruption to surface traffic, business, and other activities.''

The extensive use of trenchless construction for the installation, repair, or replacement of underground utility infrastructure is a relatively recent development; however, the use of trenchless techniques dates back to the 1860s, when Northern Pacific Railroad Company pioneered the use of pipe jacking techniques. By the 1930s, reinforced concrete pipe ranging in size from 1,070 mm (42 in.) to 1,830 mm (72 in.) in diameter had been installed using this technique. Thereafter, other methods of trenchless construction began being utilized including auger boring (1940), impact moling (1962), directional drilling (1971), microtunneling (1973), and pipe bursting (1980). A summary and listing of selected reference literature for common trenchless technologies currently employed in the municipal arena is provided in Table 1.

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TABLE 1. Information and References for Trenchless Methods

Technology (1)	Length (2)	Diameter (3)	Summary of method (4)	Cost (5)	Applications (6)	References (7)
(*a*) New Construction						
Horizontal directional drilling	120–1,800 m	25–900 mm	Two-stage process: small diameter directional hole is drilled to provide pilot hole; back reamer and product are then pulled back through pilot hole. No excavation required for installation.	\$0.50–\$0.90/mm/m length	Force mains, gravity sewers, utility conduits, geotechnical investigaton, pipelines	Kirby et al. (1997); Allouche et al. (1997); Iseley and Gokhale (1997)
Microtunneling	25–225 m	250–3,050 mm	Remotely controlled, guided pipe jacking process that provides continuous support to excavation face. Pipe installed from drive shaft to reception shaft. No person entry required in pipe.	\$1.20–\$4.00/mm/m length	Gravity sewer installations	Atalah (1997); Iseley and Gokhale (1997); Iseley and Najafi (1997); Stein et al. (1989)
Pipe jacking	Up to 490 m achieved	1,060–3,050 mm	Pipe is jacked horizontally from drive shaft to reception shaft. Workers required in pipe to perform excavation and/or remove spoil. Excavation performed either manually or mechanically.	\$0.40–\$1.90/mm/m length	Large diameter gravity sewers, force mains, diversion chambers	Miller (1996) Iseley and Najafi (1997); Tanwani (1996); Committee (1991)
Auger boring	12–150 m	200–1,500 mm	Pipe pushed from drive shaft to reception shaft, while rotating flight auger simultaneously removes spoil. This method does not apply pressure to cutting face.	\$0.10–\$0.30/mm/m length	Relatively short crossings (pipes and conduits)	Iseley and Najafi (1997); Committee (1991)
Pipe bursting	100–900 m	75–1,060 mm	Existing pipe is burst or split with use of conical shaped bursting head, while simultaneously new pipe of equal or greater diameter is pulled behind bursting head.	\$0.15–\$0.30/mm/m length	Replacement of force mains and gravity sewers	Strychowskyj (1997); Howell (1995); Everett (1997); Committee (1991)
(*b*) Rehabilitation						
Lining of pipe	Up to 1000 m	100–1,500 mm	Pipe can be relined though various methods depending on application. Lining methods can be categorized as replacement or relining methods. Replacement methods refer to insertion of new pipe inside old line, these include sliplining and spiral winding; while cured in place pipe and fold and form methods are categorized as relining method. Relining extends useful life of pipe but is not intended as structural enhancement.	Varies by method	Relining of water, sewer and natural gas lines	Brand (1997); Reyna et al. (1994); McAlpine (1991); Larsen et al. (1997); Wells (1996)
Pipe scanning and evaluation	Varies	Varies by method	Classified as group of nondestructive methods for inspecting pipes to determine their condition. Methods include sonar, impulse radar, seismic transmission, radio electromagnetic and closed-circuit television. Usually first step in evaluating existing distribution systems.	Varies by method	Inspection of existing infrastructure systems, as well as a ''snap shot'' of the pipe condition.	Martindale (1997); Hutchinson (1997); Russell and Davies (1997); Staples (1994); Tenove (1997)
Robotic spot repair	Varies	Varies by method	Involves use of remotely controlled systems for structural repair or leak control of pipes. Uses inflatable ''shoes'' as temporary forming while epoxy is injected in damaged sections and allowed to cure.	Varies by method	Repair of sewer and water lines where structural enhancement is required.	Bauhan et al. (1997)

Note: mm/m = cost in Canadian dollars/mm diameter/linear meter.

PROFILE OF MUNICIPALITIES

The geographical, demographical, and geological diversity of Canada dictates many regional differences, which influence the choice of method that a municipality employs to perform underground construction. It was important that this diversity be well sampled to receive an accurate picture of the use of trenchless construction methods across the country. The survey attempted to sample municipalities of all sizes and in all regions of the country. Subsequently, the country was categorized into four regions: (1) Western Canada (Alberta, British Columbia, Yukon, and the Northwest Territories); (2) the prairies (Manitoba and Saskatchewan); (3) the maritimes (New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland); and (4) central Canada (Quebec and Ontario). This provided a grouping of provinces with similar regional and geographical characteristics in the survey.

The survey was distributed to 87 municipalities across the four regions, representing a wide range of population size, geological conditions, and geographical areas. Responses were received from 53 municipalities resulting in a 61% response rate. Table 2 summarizes the breakdown of surveys from each region. Municipalities were grouped into seven categories based on population size, ranging from under 20,000 to over 1,000,000. Responses from most of the major metropolitan centers in Canada such as Toronto, Montreal, Vancouver, Edmonton, and Calgary as well as some of the smaller municipalities including Dauphin, Humbolt, and Stettler were included in the survey. With this diversity, trends in trenchless construction methods could be established as they relate to municipality size. The size distribution of the municipalities is shown in Table 3.

TABLE 2. Distribution of Surveys and Responses by Region

Region (1)	Number of surveys distributed (2)	Number of surveys received (3)	Response rate (%) (4)
Western Canada	37	26	70
Prairies	16	7	44
Central Canada	31	17	55
Maritimes	3	3	100
Totals	87	53	61

Information was collected from each municipality on budgetary spending for new and rehabilitation construction for the 1996–1997 construction season. Thus the relationship between the municipality size and its budget allocation could be determined. To compare the budgets for new and rehabilitation construction to the population of the municipality, municipalities were grouped into three categories: (1) Municipalities under 100,000 in population; (2) between 100,000 and 500,000;

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and (3) over 500,000. These categories were chosen on the rationale that municipalities with populations over 500,000 typically consist of congested urban areas with large underground infrastructure, much of which is 50 years old or more. Municipalities in this category include Vancouver, Calgary, Edmonton, Toronto, Montreal, Winnipeg, and Halifax. The municipalities in the 100,000–500,000 category are generally located in Ontario and Quebec, although some of the larger population centers of Saskatchewan, Manitoba and the Maritimes also fall into that category. Most of these municipalities can be characterized as having growing populations with relatively new infrastructure and less congested urban areas. The last category with municipalities under 100,000 can be characterized as the average Canadian municipality located in any region of Canada. These municipalities have a varied age and most have a smaller, less developed underground infrastructure and virtually no dense downtown area.

To compare budgets of different sized municipalities, the budgets for new and rehabilitation construction were converted into budget per capita. Population size information was obtained from the 1996 Canadian census (Statistics Canada 1997). The middle portion of the budget range provided by each municipality was taken as a representative sample to produce a budget per capita figure. This enabled the budgets for different sized municipalities to be compared. Figs. 1 and 2 illustrate the distribution of budget per capita for new construction and rehabilitation, respectively.

The distribution of data for both figures is skewed to the left, with few values greater than $200/capita. These are considered to be isolated cases that do not reflect the true nature of the distribution. The distribution for new construction revealed an average per capita budget of $55.34, with a standard deviation of $123.52 and a median value of $29.68. The rehabilitation distribution had an average per capita budget of $48.59, a standard deviation of $98.09 and a median of $18.21. The statistical analysis implies that, in general, municipalities are spending a greater portion of their annual budget on new infrastructure than on rehabilitation. Because

TABLE 3. Distribution of Responses by Municipality Size

Population range (1)	Number of responses (2)	Percent of responses (%) (3)
Under 20,000	14	26.4
20,000–49,999	10	18.9
50,000–99,999	9	17.0
100,000–249,999	4	7.5
250,000–499,999	6	11.3
500,000–999,999	7	13.2
Over 1,000,000	3	5.7
Total responses	53	100.0

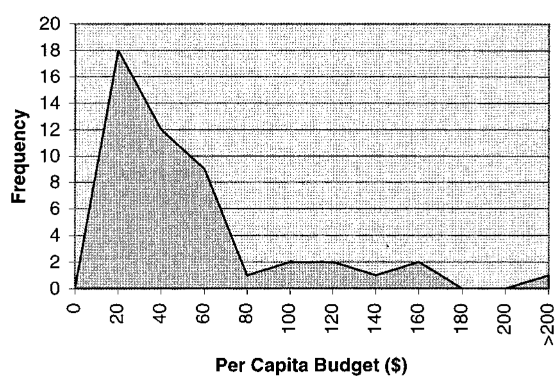

FIG. 1. Per Capita Budget for New Construction

of the presence of several extreme values (over $200/capita), the median value may be viewed as a better measure of the per capita spending for new construction and rehabilitation than the average value.

To better compare the per capita budget for various sized municipalities, the data were grouped according to the three municipality size categories, populations <100,000, populations between 100,000 and 500,000, and populations >500,000. This data is presented in Table 4 for new construction and Table 5 for rehabilitation. For each size category the minimum, maximum, mean, and median values for the per capita budget were provided, as well as the number of municipalities sampled in the category. Again, as there were some values that were on the extremes of the data group, the median values may provide a better representation of the typical level of spending per capita. For new construction, the per capita budget expenditure decreased as the size category increased. This trend can be explained by the fact that in large urban areas there are fewer meters of pipe in the ground per capita as the population density is higher. The statistical analysis indicates that overall municipalities spend less money on rehabilitation compared to new construction. This is particularly true for medium sized municipalities where the spending per capita for rehabilitation is approximately 1/10 of the spending for new construction. This may be partially attributed to the fact that five of the municipalities in this group are located in southern Ontario, one of the fastest growing regions in Canada according to Statistics Canada (1997).

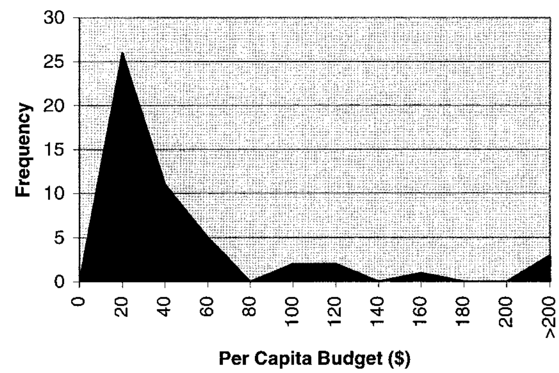

FIG. 2. Per Capita Budget for Rehabilitation

TABLE 4. Budget per Capita for New Construction by Municipality Size

Population (1)	Under 100,000 (2)	100,000–499,999 (3)	Over 500,000 (4)
Minimum (dollars)	3.99	5.32	2.68
Maximum (dollars)	865.78	53.44	29.68
Mean (dollars)	75.65	26.94	13.82
Median (dollars)	43.07	32.99	12.17
Data points	32	9	9

TABLE 5. Budget per Capita for Rehabilitation by Municipality Size

Population (1)	Under 100,000 (2)	100,000–499,999 (3)	Over 500,000 (4)
Minimum (dollars)	5.33	0.48	1.34
Maximum (dollars)	624.96	22.81	52.63
Mean (dollars)	67.71	8.61	18.48
Median (dollars)	25.17	3.74	12.13
Data points	34	9	9

The distribution of the utilization of various trenchless methods is displayed in Fig. 3, which presents the percentage of respondents that have used each technology. Of the listed trenchless technologies, it was determined that the lining of pipe was the most widely used method with 66% of the respondents indicating having used this method. The second most popular technology was auger boring with a 47.2% response rate. These two technologies were among the first trenchless technologies that were widely used in industry. Auger boring dates back to the 1940s, whereas pipe lining began to be widely used in the 1970s. Pipe jacking was the third most popular technology (43.4%), followed closely by pipe scanning and evaluation (41.5%). Among the new trenchless construction methods horizontal directional drilling is the most widely used technology, followed by pipe bursting. The least utilized technology was microtunneling (24%). The specialty nature of microtunneling and the limited number of contractors who have the capacity to perform this type of work may account for the lower utilization of this method.

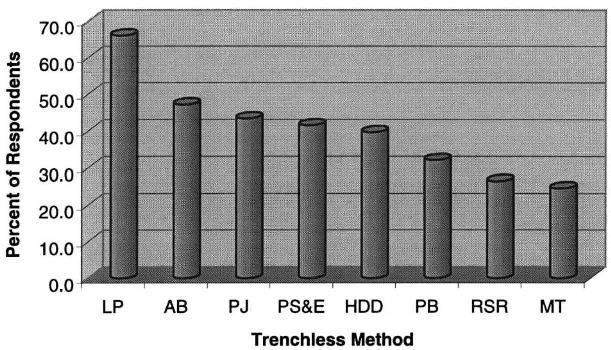

FIG. 3. Utilization of Trenchless Technologies by Respondents

GROWTH OF TRENCHLESS CONSTRUCTION

The move towards the use of trenchless technologies in the municipal arena occurred in the late 1970s as pipe lining systems were employed in an increasing frequency for the rehabilitation of the deteriorating natural gas distribution system as well as sewers and water mains. Installation of pipelines in urban environments for appreciable distances first became possible with the introduction of microtunneling to North America in 1984. Since the late 1980s trenchless technologies have been experiencing a rapid growth in popularity. The advancement of existing technologies (i.e., inverted lining and form and fold) and the development of new technologies (i.e., robotic spot repair) made trenchless technologies a preferred method of rehabilitation on many projects. As for new construction, pipe bursting and horizontal directional drilling—both oil field technologies that were adapted to municipal applications—brought a new dimension to underground construction. These technologies allowed for the quick replacement or installation of new conduits from 25 mm (1 in.) to 1,200 mm (48 in.) in diameter, with minimum surface disruption, at a cost that in many cases is competitive with open excavation.

The survey indicates that trenchless construction methods are not unfamiliar to most municipalities across the country, as 94% of the respondents indicated that their municipality had utilized a trenchless technology at least once in the past. Furthermore the use of trenchless technology is on the rise, increasingly viewed as an alternative to conventional open cut methods.

To evaluate the growth of the trenchless construction industry in the Canadian municipal sector in Canada, one can compare its use by municipalities for new construction and for rehabilitation of existing lines today and 5 years ago. A comparison of the percentage of trenchless technologies utilized in new construction in Canadian municipalities today versus 5

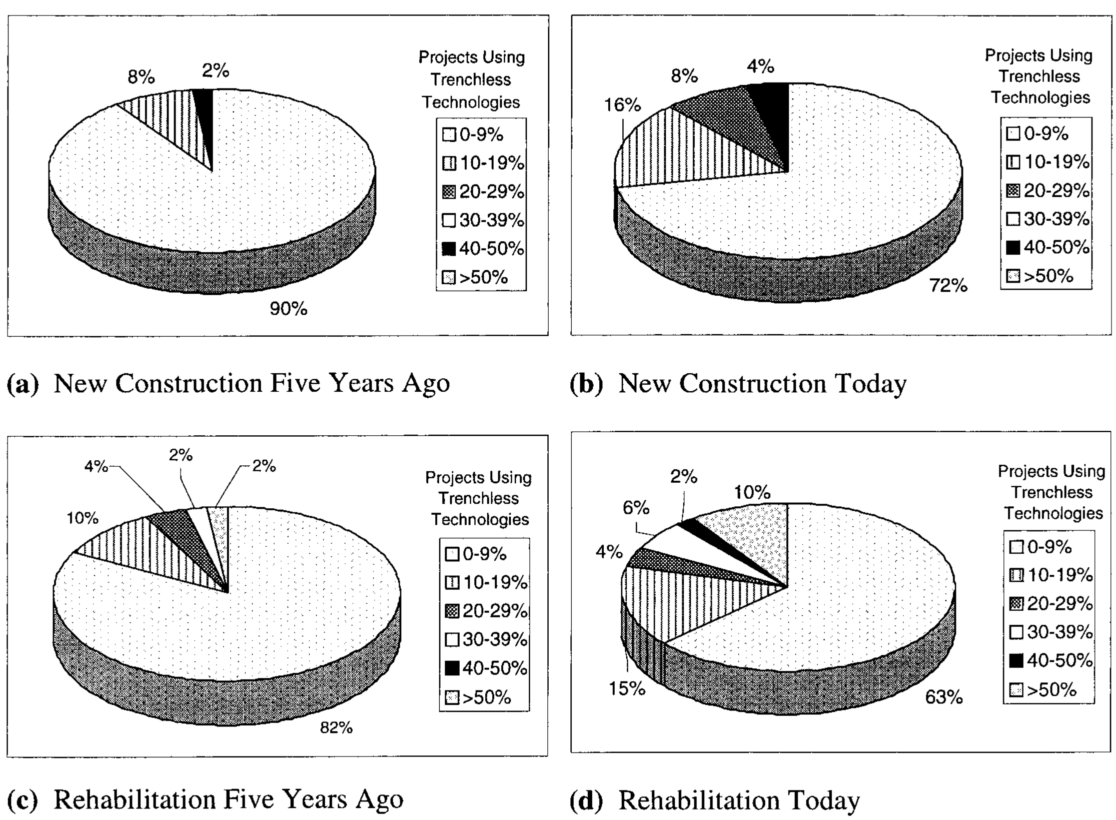

FIG. 4. Comparison of Utilization of Trenchless Technology in New and Rehabilitation Construction 5 Years Ago and Today

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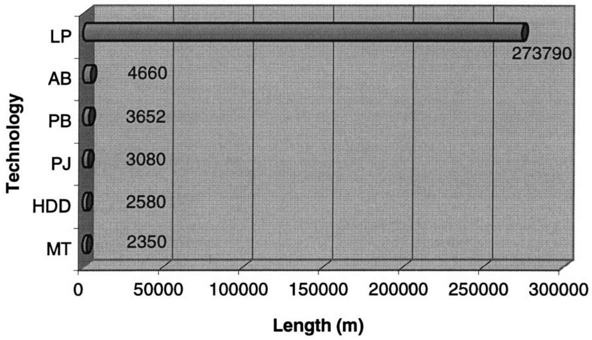

FIG. 5. Linear Meters of Pipe Installed

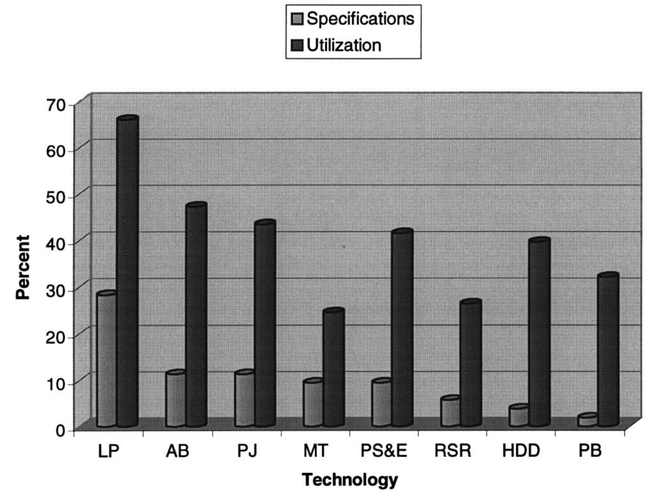

FIG. 6. Percentage of Respondents Having Contractor Selection Specifications Compared with Utilization for Various Trenchless Methods

years ago is represented in Figs. 4(a and b), respectively. Ten percent of the respondents indicated that they used trenchless technologies on 10% or more of their new construction 5 years ago, whereas today this fraction has increased to approximately 28%. This represents a 180% increase in the use of trenchless technologies on new construction over the past 5 years. Similarly, Figs. 4(c and d) illustrate the percentage of all repairs and rehabilitation to pipeline and utility conduit utilizing trenchless construction. Approximately 18% of the respondents indicated that they used trenchless technology on 10% or more of their projects 5 years ago. Today, this figure has risen to 37% indicating a growth of 270% over the past 5 years in the area of trenchless technology rehabilitation. The survey indicates that there has been a significant increase over the past 5 years in the utilization of trenchless methods of construction in Canada for both new and rehabilitation projects.

To gain a better understanding of the volume of trenchless construction undertaken by Canadian municipalities, the survey collected data on the number of linear meters of pipe that was installed or rehabilitated using trenchless methods in the 1996–1997 construction season. Data were collected on the volume of installed pipe in linear meters for horizontal directional drilling, auger boring, pipe bursting/splitting, pipe jacking, microtunneling, and lining of pipe, as indicated in Fig. 5.

The survey indicated that of the six trenchless construction methods listed over 94.4% of the total length of pipe installed or rehabilitated was completed using pipe lining methods. The five other trenchless methods accounted for the remaining 5.6% of the total length installed. The large proportion of lined pipe installed may be accounted for by the familiarity of the pipe lining technology and the fact that specifications and construction practices for pipe lining are well established in many parts of the country.

CONTRACTOR SELECTION METHODS

Careful selection of a contractor is important for a successful project as well as the responsible use of public funds. Two popular methods of contractor selection are the use of specifications and contractor prequalification. In the survey, we attempted to determine the extent to which these control measures are utilized in the practice of selecting contractors in the municipalities for trenchless projects.

The survey analysis revealed that established guidelines or specifications for contractor selection are not widely used. Fig. 6 compares the percentage of the total responding municipalities that have guidelines or specifications for the selection of a contractor that offers a service in a particular trenchless method to the percentage of the total responding municipalities that have used this trenchless method. On projects involving lining of pipe, which is the most popular trenchless method, only 28.3% of the municipalities surveyed used contractor selection specifications. This indicates that only half of the municipalities that use lining technology have specifications for contractor selection. Both auger boring and pipe jacking had the second most usage of selection specifications with 11.3% of the total respondents indicating they use specifications for contractor selection for these technologies. When compared to the total utilization of those technologies, it was revealed that only about a quarter of the municipalities that used auger boring and pipe jacking had contractor selection specifications. Additionally, approximately a tenth of those municipalities that have used horizontal directional drilling have specifications for contractor selection. These results indicate that the utilization of specifications in contractor selection on trenchless projects is currently very low in Canada. The development of contractor selection guidelines could be an area of future research.

The next method of contractor selection identified in the survey was contractor prequalification. Prequalification is a useful method to assist in the selection of contractors that have the capacity to perform the project. In this survey, the prequalification practices of municipalities were studied to determine if the practice differed for trenchless projects over nontrenchless projects. From the survey analysis, it was apparent that if a municipality practiced contractor prequalification, it used prequalification on all contractor selection regardless of whether or not it was a trenchless contractor. It was determined that 84% of the municipalities used the same prequalification methods for trenchless contractors as they used for nontrenchless contractors.

In the selection of a contractor, there are several factors that contribute to the final decision. Every municipality will weigh factors differently based on that municipality's previous experience in contracting out work. The survey attempted to determine how important certain factors were in the choice of a contractor for a project involving trenchless technologies. Six major factors were identified including adequate contractor bonding, safety program, innovations in design or construction methods, previous experience, equipment availability, and locality. From the results of the survey it was apparent that the most important factors in determining the choice of a contractor for a project involving trenchless technologies was that the contractor have adequate bonding. The second most important factors presented were that the contractor had an established safety program and previous experience. Both innovations in design and construction method and equipment availability were identified as important. The locality of the contractor was

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identified as only somewhat important and was the least determining factor in contractor selection.

FUTURE GROWTH

The use of trenchless technologies is expected to increase as more contractors and municipalities become familiar with their applications and aware of their advantages. Municipalities were asked to rank the technologies that they felt had the most potential for future growth. The results indicated that for new construction methods the most potential growth was in horizontal directional drilling, followed by pipe bursting, auger boring, microtunneling, and pipe jacking. In rehabilitation construction, lining of pipe was determined to have the greatest potential growth followed by pipe scanning and evaluation and robotic spot repair.

COMMENTS FROM SURVEY RESPONDENTS

The following list is a sample of comments made by select survey respondents:

- ''This method will gain popularity as more contractors gain experience and can offer the service. Prices should drop and more use will be made; with more widespread use comes education and sharing work experience thus promoting further use by engineers in the positions where decisions to use new technologies are made.''
- ''More trenchless technology will be utilized to line sanitary and storm sewers which have high rates of infiltration.''
- ''Trenchless technology is highly suited to the installation and rehabilitation of underground utilities in urban environments. As engineers/contractors become more familiar with its potential and construction costs decrease the percentage of underground installations by these methods will increase.''
- ''I generally feel there is a potential of saving 20–40% in the cost of rehab using no dig solutions. Based on the current value of our collection system, the savings would potentially be <$100 M (based on life cycle replacement costs).''
- ''I am very enthused with the field. I am a leader in the push for more work to be done in our city. I keep up to date on new advances and am willing to try new ideas to help lower costs.''

DISCUSSION

The growth in trenchless construction methods has been inspired by the many benefits of this technology. Trenchless technologies allow for the completion of complex underground infrastructure projects in congested urban areas in a safe, economical manner with minimal disruption to surface traffic, nearby businesses, or environmentally sensitive areas.

This growth may be accounted for by several reasons. First, as trenchless technologies mature, they have become more sophisticated, cost effective, and accurate. An example is the growing use of horizontal directional drilling methods to place gravity sewers. The degree of accuracy in placement required by this application could not have been achieved 5 years ago using the horizontal directional drilling method.

In addition, as the attitudes of the commercial sector and the general public change, it becomes increasingly more important to consider social costs associated with construction projects. The increasing awareness of user costs and the demand for different approaches for solving infrastructure problems has led to the increased utilization of trenchless technologies.

The use of trenchless technologies is also promoted by the trend of environmental regulations becoming more stringent, making it more difficult to obtain permits to perform construction activities in environmentally sensitive areas. Trenchless technologies provide an environmentally friendly approach to performing work that would have traditionally been performed by open cut methods.

Finally, underground congestion of utilities is on the rise, particularly in larger municipalities. It becomes increasingly more difficult to install deep utilities, as there may be several levels of utility corridors encountered at shallower depths. Each utility must be supported during excavation and then carefully backfilled to protect it from damage or future settlement. This results in open cut excavation being expensive and slow in congested underground areas. By utilizing trenchless solutions, some of these costs and difficulties may be avoided. In addition, in the case of deep excavations trenchless technologies require a smaller right-of-way than that required when using the open cut method, an advantage that may be particularly appealing in the case of a limited right-of-way.

From the survey, it appears that research is required in the development of specifications and guidelines for design, contractor selection, and management of trenchless projects. In addition, decision support systems should be developed to aid municipal planners and engineers in the evaluation and selection of trenchless construction methods for a particular project.

The utilization of trenchless methods is expected to continue to increase in Canadian municipalities as more contractors gain experience and can offer the service. Another key factor for the acceptance of trenchless technologies, and its wider use in the municipal arena, is education and sharing of work experience by engineers and others that hold positions where decisions regarding the use new technologies are made.

CONCLUSIONS

Based on the survey results the following conclusions were made regarding the utilization of trenchless construction methods by Canadian municipalities:

1. Over 90% of the municipalities surveyed indicated that they had employed at least one method of trenchless construction in the past.
2. Over the past 5 years, the utilization of trenchless methods for new construction and rehabilitation has experienced a growth of 180 and 270%, respectively.
3. Based on the median value, Canadian municipalities spend $29.68/capita on new construction and $18.21/capita on rehabilitation.
4. Lining of pipe methods for rehabilitation is the most utilized trenchless technology by Canadian municipalities. Lining of pipe accounted for 94% of the total length of pipe rehabilitated or constructed during the 1996–1997 construction season. In addition, 66% of the respondents had utilized lining methods in the past.
5. Established guidelines and specifications are not widely used as the ratio of the percentage of respondents having contractor selection specifications compared with the utilization of the various trenchless methods range between 0.1 and 0.4.
6. Trenchless technologies that are expected to experience the greatest future growth are horizontal directional drilling and pipe bursting for new construction and lining of pipe methods for rehabilitation.

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APPENDIX I. SURVEY QUESTIONNAIRE

University of Alberta
Construction Engineering and Management
Survey of Trenchless Technology in Canada

CONFIDENTIAL

Please complete and either mail or fax to: (403) 492-0249. ATTN: Dr. Samuel T. Ariaratnam

Trenchless Technologies

1. Region (please check applicable box):

   Western Canada (Alberta, BC, Yukon, NWT) .... ❐
   Prairies (Manitoba, Saskatchewan) .... ❐
   Maritimes (NB, Nova Scotia, PEI, Nfld.) .... ❐
   Central Canada (Quebec, Ontario) .... ❐

2. What is the population of the municipality/city/region that you are responsible for? (please check applicable box):

   ❐ under 20,000 ❐ 100,000 – 249,000 ❐ 500,000 – 999,999
   ❐ 20,000 – 49,999 ❐ 250,000 – 499,999 ❐ over 1,000,000
   ❐ 50,000 – 99,999

3. What is your agency's annual utility infrastructure budget for:

   New Construction:

   ❐ under $500,000 ❐ $2.5 M – under $5 M ❐ $10 M – under $25 M
   ❐ $500,000 – under $1 M ❐ $5 M – under $10 M ❐ $25 M +
   ❐ $1 M – under $2.5 M

   Rehabilitation:

   ❐ under $500,000 ❐ $2.5 M – under $5 M ❐ $10 M – under $25 M
   ❐ $500,000 – under $1 M ❐ $5 M – under $10 M ❐ $25 M +
   ❐ $1 M – under $2.5 M

(*Appendix I Continues*)

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4. Has your agency ever utilized trenchless technologies? (please circle) Yes No

If yes, please indicate all relevant technologies:

☐ Pipe Bursting/Splitting	☐ Lining of Pipe	☐ Horizontal Directional Drilling
☐ Microtunneling	☐ Auger Boring	☐ Pipe Scanning & Evaluation
☐ Robotic Spot Repair	☐ Pipe Jacking	☐ Other ________________

5. What percentage (approximately) of all new pipeline and utility conduit construction executed by your agency employ trenchless technologies?

Five years ago,
☐ 0-9% ☐ 10-19% ☐ 20-29% ☐ 30-39% ☐ 40-50% ☐ over 50%

Today,
☐ 0-9% ☐ 10-19% ☐ 20-29% ☐ 30-39% ☐ 40-50% ☐ over 50%

6. What percentage of all repairs and rehabilitation to pipeline and utility conduit construction executed by your agency employ trenchless technologies?

Five years ago,
☐ 0-9% ☐ 10-19% ☐ 20-29% ☐ 30-39% ☐ 40-50% ☐ over 50%

Today,
☐ 0-9% ☐ 10-19% ☐ 20-29% ☐ 30-39% ☐ 40-50% ☐ over 50%

7. In 1996-97, how many meters of pipe were installed/rehabilitated using the following trenchless technologies:

Trenchless Technology	Length of Pipe (m)
Horizontal Directional Drilling	____________
Auger Boring	____________
Pipe Bursting/Splitting	____________
Pipe Jacking	____________
Microtunneling	____________
Lining of Pipe	____________

(*Appendix I Continues*)

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8. Does your agency currently have any established guidelines (or specifications) for the selection of a contractor in the following areas? (please check applicable boxes)

❐ Pipe Bursting/Splitting	❐ Lining of Pipe	❐ Horizontal Directional Drilling
❐ Microtunneling	❐ Auger Boring	❐ Pipe Scanning & Evaluation
❐ Robotic Spot Repair	❐ Pipe Jacking	❐ Other ________________

9. What percentage of trenchless projects that you tender require contractor pre-qualification?

❐ 0-24% ❐ 25-49% ❐ 50-74% ❐ 75-100%

10. What percentage of non-trenchless projects that you tender require pre-qualification?

❐ 0-24% ❐ 25-49% ❐ 50-74% ❐ 75-100%

11. How important are the following factors in determining your choice of contractor for a project involving trenchless technologies?

	very important	important	somewhat	not at all
Adequate bonding	❐	❐	❐	❐
Safety program	❐	❐	❐	❐
Innovations in design or construction method	❐	❐	❐	❐
Previous experience	❐	❐	❐	❐
Availability of equipment	❐	❐	❐	❐
Locality	❐	❐	❐	❐

Others- please specify ____

12. What is your overall impression of trenchless technologies, please comment?

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(*Appendix I Continues*)

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13. Where do you foresee the most future growth in trenchless technologies for municipal applications? (Please rank for each category from 1 to 5, 1 being the most promising)

New Construction		Rehabilitation	
HDD	________	Lining of Pipe	________
Microtunneling	________	Pipe Scanning & Evaluation	________
Pipe Jacking	________	Robotic Spot Repair	________
Auger Boring	________	Other - please specify	____________
Pipe Bursting	________		
Other - please specify	____________		

APPENDIX II. PARTICIPATING MUNICIPALITIES

The writers would like to acknowledge the following Canadian municipalities for participating in the survey. Their input and insight were invaluable in completing this research project.

City of Airdrie, Alberta
Town of Ajax, Ontario
Aqualta, Alberta
Town of Athabasca, Alberta
Town of Banff, Alberta
Town of Beaumont, Alberta
Town of Bonnyville, Alberta
City of Brandon, Manitoba
City of Brantford, Ontario
City of Calgary, Alberta
City of Camrose, Alberta
County of Parkland, Alberta
City of Dauphin, Manitoba
City of Drumheller, Alberta
City of Edmonton, Alberta
City of Etobicoke, Ontario
Regional Municipality of Wood Buffalo, Alberta
City of Fort Saskatchewan, Alberta
City of Fredericton, New Brunswick
Greater Vancouver Regional District, British Columbia
Regional Municipality of Halifax, Nova Scotia
Regional Municipality of Hamilton-Wentworth, Ontario
Town of Humboldt, Saskatchewan
City of Leduc, Alberta
City of Lethbridge, Alberta
City of Lloydminster, Alberta
City of Medicine Hat, Alberta
City of Moncton, New Brunswick
Ville de Montreal, Quebec
City of Nepean, Ontario
City of Newmarket, Ontario
City of Niagara Falls, Ontario
City of North York, Ontario
City of Peterborough, Ontario
City of Prince Albert, Saskatchewan
Town of Rocky Mountain House, Alberta
City of Saskatoon, Saskatchewan
City of Scarborough, Ontario
Scarborough Public Works Commission, Ontario
City of Spruce Grove, Alberta
City of St. Albert, Alberta
Town of Stettler, Alberta
Strathcona County, Alberta
Regional Municipality of Sudbury, Ontario
City of Thunder Bay, Ontario
Corporation of the City of Toronto, Ontario
City of Vancouver, British Columbia
City of Victoria, British Columbia
City of Waterloo, Ontario
Regional Municipality of Waterloo, Ontario
City of Whitehorse, Yukon Territories
City of Winnipeg, Manitoba
City of Yellowknife, Northwest Territories

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APPENDIX IV. NOTATION

The following symbols are used in this paper:

AB = auger boring;
HDD = horizontal directional drilling;
LP = lining of pipe;
MT = microtunneling;
PB = pipe bursting;
PJ = pipe jacking;
PS&E = pipe scanning and evaluation; and
RSR = robotic spot repair.

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