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# Executive Summary

## **Socio-Economic Cost Assessment for Damages to Underground Infrastructures**



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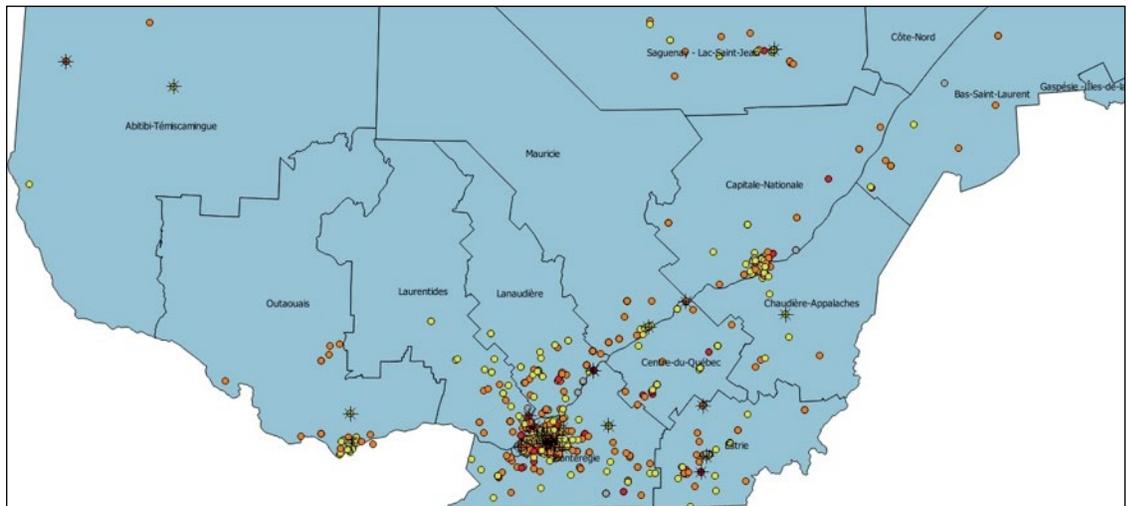
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## Background and key issues

Vast networks of conduits and cables lie underground, delivering products and services to today's society. Underground infrastructures include telecommunication and electrical cables, gas conduits, sewers, water lines, drainage systems, oil pipelines, etc. The increasing number of

networks, along with the fact that they are buried not far from the ground's surface translate into contractors striking them frequently while doing excavation or rehabilitation work of all kinds.



**Figure 1** Damage distribution for 2014 per region and based on the type of underground infrastructures (Gas = Yellow ; Telecommunication = Orange ; Electricity = Red ; Others = Grey ; Star = Service interruptions of 5 hours or more)

### Alarming Statistics Concerning Damages

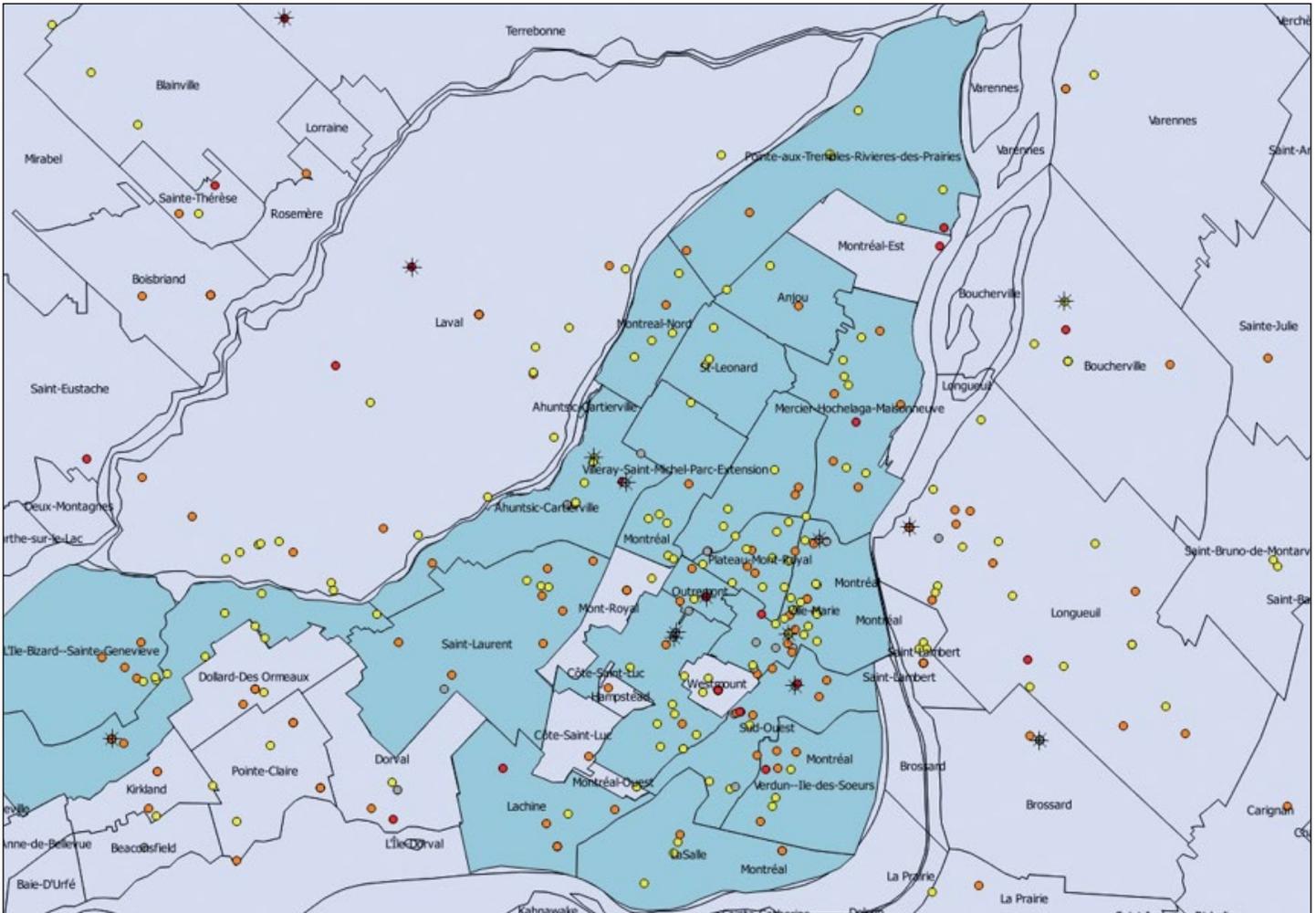
In 2014, there was an average of 5 damaged underground infrastructures per day in Quebec. In 34 % of cases, no locate request had been made to Info-Excavation. As per Section 3.15.1 of the Quebec Safety Code for the Construction Industry: "Before digging, the employer shall verify whether there is underground piping within the perimeter of the works to be carried out and, where applicable, situate its exact location on the ground". More alarmingly still is that the numbers are certainly higher than those documented since reporting is made on a voluntary basis and many underground infrastructure owners do not participate, to date, in the data collecting program put forth by

Info-Excavation. Furthermore, in 35 % of cases the intervention of municipal emergency services was required and 84 % resulted in service interruptions (Source: Info-Excavation, 2014).

When mapping damages throughout Quebec, we see that they are mainly located in the southern part of the province, mostly in cities with higher population densities such as Montréal, Québec and Gatineau. Most of them are done to telecommunication network and gas conduits (Fig. 1). Regardless of the type of excavation work done by excavators, more than two-thirds of damages happen in the Greater Montréal area which includes Montérégie, Montréal, Laval, Lanaudière and the Laurentian.

For the Montréal island, some boroughs such as plateau Mont-Royal, Ville-Marie and Verdun have a higher concentration of damages than others

(Fig. 2). Analysis showed that there is a correlation between population density of Montréal boroughs and the number of damages.



**Figure 2** Damage distribution in Montréal for 2014 based on the type of underground infrastructures (Gas = Yellow ; Telecommunication = Orange ; Electricity = Red ; Others = Grey ; Star = Service interruptions of 5 hours or more)

### Damages Endanger People and Workers

People, more specifically workers, are endangered since they are exposed to serious injuries and situations that may become deadly. In the province of Quebec, no deaths have been reported following damages to underground infrastructures. However, there have been fatal accidents in other provinces. Since 2003, Ontario had 7 fatal accidents. British Columbia had 2 fatal accidents and 6 seriously injured workers since 2008; all of them were due to damaged underground infrastructures by excavation work (an average of 1,600 infrastructures

struck annually). In the United-States, the US Department of Transportation, the Pipeline & Hazardous Materials Safety Administration compiles each year serious accidents for each type of pipeline operators. American statistics are quite alarming. Since 2008 damages done to underground infrastructures by excavation work injured 98 people and killed 17 <sup>2</sup>.

<sup>2</sup> US DOT, PHMSA Serious Pipeline Incidents, available on the following Web page, consulted on July 24, 2015: <https://hip.phmsa.dot.gov/analyticsSOAP/saw.dll?Portalpages>

## Purpose of research: Identify and quantify socio-economic costs for damages to underground infrastructures

Every damage done to underground infrastructure inevitably entails a cost. There are two types of costs:

**Direct Costs** arise from repairing the damage done.

**Direct Costs** are related to the following damages:

- Costs of replacement materials used
- Costs of materials used
- Labour costs
- Administrative costs needed to rehabilitate the damaged infrastructures

**Indirect Costs** arise from the damage.

These costs reflect the economic assessment of all disruptions related to damages done to underground facilities. They are varied and can cover a wide range of areas. They can represent a service disruption, affect the workers' health and safety as well as that of emergency service employees, cause traffic disturbances, mobilize emergency services or represent the administrative costs related to the procedures that arise from such accidents. In addition, we must add the costs related to environmental impacts (noise, vibrations and all forms of pollution) as well as those related to the economic impacts (loss of revenue, absenteeism and lateness for work, etc.). In most cases, these additional costs are incurred by society.

The overall costs is the total damage related cost to underground infrastructures. If a network's repair cost is relatively easy to identify and allocate to a given damage, the same cannot be said of indirect costs; they are difficult to quantify and rarely taken into account when making decisions related to excavation work or prevention.

*The general purpose of this research is to identify and quantify not only the direct costs, but to assess indirect costs entailed by damages done to underground infrastructure in the province of Quebec. The study will be used towards damage prevention and as an incentive for best practices amongst contractors, municipalities and owners of underground infrastructures and clients.*

This project is even more relevant since urban networks are now often buried for aesthetic reasons (effort to repossess the landscape) or for security reasons (risk reduction due to climate incidents and risk eliminated by the presence of vegetation in urban environments). In this respect, the importance of improving underground network management takes on an even greater dimension.

Four specific objectives have been established to carry out the research project:

- 1. Develop a typology for damage related direct and indirect costs for underground infrastructures.*
- 2. Quantify total related costs for four types of damages to underground infrastructures in the province of Quebec and estimate the ratio between direct costs and indirect costs.*
- 3. Develop an assessment methodology for damage related indirect costs for the province of Quebec and assess the total indirect costs for 2014.*
- 4. Examine Info-Excavation's database to identify key factors behind damages, leading to a more effective damage prevention program.*

## Result No 1: Damages can lead to a wide range of indirect costs

A literature review helped identify the different types of damage related costs for underground infrastructures. The goal was to associate each cost item with an estimation method.

Direct costs represent the tip of the iceberg, which is quite small compared to what lies underneath. In fact, the list of indirect costs is often longer; many of them being forgotten. Here is a list of key damage related indirect costs that might occur:

### Service Disruption Following Damages to Infrastructures.

A service disruption of a client's electrical network may, for example, represent thousands of dollars in hourly costs. They may increase rapidly when the service disruption touches businesses or institutions. It's important not to overlook the fact that damages to gas conduits often lead to electrical service disruptions.

### Intervention of Emergency Services.

When a gas conduit is damaged, firefighters are often required on-site, and in some instances, emergency services may also be required for safety purposes. Costs related to mobilizing emergency services and their employees are significant. They may be accompanied by opportunity costs that are just as important if, for example, first responders being on-site prevents them from responding, within a normal delay, to a call that requires immediate assistance (i.e. cardiac arrest).

### Evacuating Businesses and Residential Sectors.

In certain cases, emergency services are forced to evacuate these sectors when there is a security risk.

### Risk of Injury and Death.

When an underground infrastructure is damaged, its employees are exposed to additional risks during repair activities (related to gas leaks and overlapping work between employees of different networks, etc.).

### Loss of Product.

This cost greatly depends on the type of product that is lost and the size of the damaged infrastructure. It may not apply for telecommunication and electrical infrastructures, but such is not the case if the damaged infrastructure was used for transporting gas, hydrocarbon or water.

### Environmental Impact.

Among environmental impacts, we find noise and vibrations which affect the productivity of employees that are victims of such disturbances as well as the loss in market value of buildings during major repair work. As for pollution, it comes in two different forms. The first is made up of fine particulates such as greenhouse gas emissions and other emissions made by fuel over-consumption during traffic congestions. The second is dust production made during repair work on damaged underground infrastructures.

### Economic Impact on Businesses and Companies.

A decrease in turnover due to service interruptions (payment methods/Internet, etc.), lateness or absenteeism (due to traffic congestion, etc.), inventory loss or equipment damage due to an electrical disruption of service.

### Work Delays.

The time lost stopping the leak, repairing a conduit, etc., often causes worksite delays; causing late penalty fees for contractors (who are responsible for the damage or who must come after the contractor during a construction phase), cost overruns due to overtime work or the extra personnel hired in order to address such delays. Furthermore, the worksite may be closed for legal reasons or for investigation purposes when there are injuries. All this entails additional costs.

## Result No 1: Damages can lead to a wide range of indirect costs (continued)

### Administrative and Legal Costs.

During a flood, for example, the costs will be recorded under administrative costs so as to deal with complaints and claims. These costs may be supported by municipalities or by insurance companies.

### Negative Impact for Owner Companies.

This factor is hard to quantify. However, when an underground infrastructure is damaged, the network's vehicles marked with the company's name are often on-site and may cause traffic disturbances. Being visible, they may have a negative impact on the company's reputation. Furthermore, service interruptions may also tarnish the company's image.

### Disturbances to Neighbouring Lands and Infrastructures.

Damages to water pipes can sometimes cause excess pressure on the entire network. This in turn can translate into damages in the water main.

### Traffic Disturbances.

These costs fall under many categories: time loss because of traffic congestions, detours, fuel over-consumption from both previously mentioned effects as well as the increase in vehicle maintenance costs. It should be noted that traffic congestion affects the driver's behaviour and may cause traffic accidents.

To date, no one knows precisely what is the actual cost to businesses, municipalities and society at large, when underground infrastructures are damaged in the province of Quebec. The extent of such costs must be measured precisely. Many players bear the brunt of those costs, not only the one causing the damage.

## Direct costs

## Indirect costs

Service Disruption Following Damages to Infrastructures

Intervention of Emergency Services

Evacuating Businesses and Residential Sectors

Risk of Injury and Death

Loss of Product

Environmental Impact

Economic Impact on Businesses and Companies

Work Delays

Administrative and Legal Costs

Negative Impact for Owner Companies

Disturbances to Neighbouring Lands and Infrastructures

Traffic Disturbances

## Result No 2: Case studies representing the importance of damage related indirects costs in the province of Quebec

Four case studies were used to illustrate the evaluation methods regarding different types of costs and to assess the ratio between indirect and direct costs. These case studies are meant to represent damages to underground infrastructures in the province of Quebec. They have been chosen to illustrate different types of infrastructures that can be damaged (telecommunication, gas and water), damages of various size as well as different cost elements that were presented in the literature review. The case studies serve to highlight the importance of damage related indirect costs. Quite often, indirect costs will represent 90 % of total costs.

### Case Study (1): Damaged Gas Conduit in the Downtown Area of a Large Agglomeration in the Province of Quebec.

The first case study represents a **damage to a main gas conduit in the downtown area of a large agglomeration (Montreal)**. This type of damage is frequent in this city and requires the intervention of the fire department. According to statistics from the fire department, there is an average of 400 damaged gas conduits in Montréal each year. The presence of **41 firefighters and 11 emergency response vehicles were needed for over 1h30 in response to a damaged gas conduit. The estimated cost was over \$12,000.** Every gas leak in Montréal automatically triggers the deployment of first responders. Furthermore,

even if a gas conduit has been damaged, it is increasingly common, for safety reasons, to order a **power outage in the perimeter surrounding the leak**. In this case, **1,720 Hydro-Québec customers were touched by this power outage** which lasted over 1h30. Even if no congestion was reported, **results show that more than 99% of costs due to this damage were in fact indirect costs**. Direct costs consisted of labour costs as well as the material and equipment needed to repair the gas conduit.



## Result No 2: Case studies representing the importance of damage related indirects costs in the province of Quebec (continued)

### Case Study (2): Damaged Telecommunication Network of a Large Agglomeration in the Province of Quebec

The second case study represents a **damaged telecommunication underground infrastructure in a large agglomeration (Montréal)** located at the corner of Jean-Talon and Côte-des-Neiges, a **major Montreal arterial road**. Repair work, which took **23 days to complete**, caused important traffic congestions. If we take into account the costs related to time loss, fuel over-consumption, pollution and the increase in vehicle maintenance costs, we arrive at a **total indirect cost of more than \$330,000 (solely related to traffic congestions)**. This case study not only helped establish the size between the different costs related to congestion, but the costs related to detours. Furthermore, costs that are harder to quantify, such as the loss

of reputation for the telecommunication company, must also be taken into consideration. In fact, during the damage and the 23 repair days that followed, many company marked vehicles were seen on-site and caused traffic congestions. By surveying motorists, pedestrians and merchants in the area, we realized very quickly that the blame was put on the visible player, in this case the telecommunication company, even though the damage was caused by a third party to begin with. In this case, **the total costs can be divided into direct costs, which represent 12% and indirect costs which represent 88% of the total costs.**



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## Two case studies reflecting damages to a water line

### Case Study (3): Minor Damages to a Water Pipe of an Average Agglomeration in the Province of Quebec

The third case study represents a **water line breakage in a residential sector of a medium-sized city (Gatineau)**. This case study helped us assess indirect costs for smaller damages done to underground infrastructures. Costs are related to a boil water advisory (laboratory tests, costs of communications to citizens, etc.), to traffic congestions and detours as well as the loss of drinking water. Even if indirect costs (estimated at approximately \$3,900) for this type of damage represent only 34 % of total costs, **this percentage takes on a new**

**meaning when we consider its recurrence. In Gatineau, for example, the city's water lines suffer from 200 breakdowns per year.** Even if indirect costs related to these minor damages make up a small portion of the total costs, these indirect costs are important and must be factored in. To date, the recurrence of this type of damage makes it a real concern in terms of costs, as well as in terms of security and comfort for citizens living in the affected area.

### Case Study (4): Major Damages to a Water Pipe in a Town in the Province of Quebec

The last case study represents a **large water pipe breakage in a town in Québec**. This study helped assess total costs related to large scale damages and their major impacts. Its importance also helped highlight the impact of a domino effect. Over and above the direct and indirect costs mentioned beforehand, additional indirect costs occurred due to secondary impacts from the main damage. **In such instances, closing the main conduit caused an excess pressure on the network of an adjacent neighbourhood which, due to the age and fragility of its water pipes, caused minor damages on the secondary conduits.**

Direct costs represented 18 % of the total estimated costs (more than \$1,100,000) when considering the initial. Indirect costs were only 14 % of total costs before adding the secondary damages that occurred due to the initial damage.

**These case studies have revealed that depending on the type, the importance of damage and its location, the ratio between direct and indirect costs vary. In most cases, indirect costs are far greater than direct costs.**

### Result No 3: Rigorous methodology to assess the total annual indirect costs related to damages

A general assessment methodology was developed to evaluate total indirect costs related to damages and to integrate the various types of costs associated with the damaged infrastructure. Four types of costs are included in the indirect cost estimation:

- Cost of electrical service interruption (**E**)
- Cost for emergency service intervention (**S**)
- Cost of traffic congestion (time loss, vehicle wear and tear, pollution) (**C**)
- Cost of Internet service interruption (**I**)

The total of indirect costs is the sum of indirect cost for every damage done which in turn corresponds to the sum of the various hourly costs allocated multiplied by the elapsed time of the incident:

$$\sum_{i=1}^N \sum_{t=\{E,S,C,I\}}^T C_t(h_i)$$

Hence:  $C_t$  = Hourly costs per type  $t$   
 $(h_i)$  = Elapsed time of the incident  $i$  in hours

It should be noted that given the available information, we have established that the length of equipment failure corresponded to the length of service interruption. This hypothesis tends to underestimate costs since service is often restored while, due to repair work, traffic congestions remain. In instances where no information was available on the length of equipment failure, and based on case studies made in Québec, we allotted 1 h 30 min to an equipment failure for an electrical network and 2 h for other types of equipment. Costs are assessed by the type of infrastructure damaged during the incident. The following table (Table 1)

gives a summary of allocated costs based on the type of damaged infrastructure.

#### Cost Assessment for Electrical Service Interruption (E)

The calculation method used takes into account the following indirect costs: equipment damaged by service interruption, paid salaries without production, lost sales or production. The cost assessment is net from saved costs due to interruption (e.g. unpaid salaries, saved energy costs). It also takes into account that certain industries use generators during a power failure. Cost assessment for an electrical service interruption is based, among other things, on a meta-analysis done in 2009 and updated in 2015 by the Berkeley Lab, affiliated to the University of California at Berkeley, and financed by the Office of Electricity Delivery and Energy Reliability of the U.S. Department of Energy (Sullivan and al., 2015). Data obtained for this study were used for assessment, once adapted to reflect the province's industrial mix. To achieve this, the percentage of gross domestic product for Quebec was taken by industry as per the North American Industry Classification System (NAICS) and used for the purpose of providing a customer damage function and produce estimates.

Cost functions used for every client-type are increasing affine functions. As an example, 1 hour of service interruption entails costs of about \$5 for a residential customer, \$900 for an average customer (business or industry with less than 50 employees) and more than \$6,000 for a major customer (business or industry with more than 50

Type of damaged infrastructure	Type of indirect costs taken into account
Electrical	Cost of electrical service interruption. Cost of Internet service interruption. Cost of traffic congestion.
Gas conduit	Intervention of emergency services. Cost of Internet service interruption. Cost of electrical service interruption. Cost of traffic congestion.
Telecommunication	Cost of Internet service interruption. Cost of traffic congestion.
Drainage and water lines	Cost of traffic congestion.
Other	Cost of traffic congestion.

Table 1 Allocated costs based on the type of damaged infrastructure

employees). Regarding the proportion of customers affected by the electrical service interruption brought on by a damaged infrastructure in Quebec (Pk), the assessment was made by taken one of the case studies and adjusting it to reflect the population density. The total number of customers by consumption category and by administrative region was obtained from Hydro-Québec. The cost related to an electrical service interruption for a given damage was calculated by the following formula:

$$C_E(h_i) = P_R N_R C(h_i, R) + P_m N_m C(h_i, m) + P_M N_M C(h_i, M)$$

- $N_k$  = Total number of clients for type  $k$  within a given region  
( $k$  can take the value of  $R$  for residential customers,  $m$  for average customers and  $M$  for major customers)  
 $P_k$  = Pourcentage of clients of type  $k$  affected by the damage  
 $C(h_i, k)$  = Estimated costs after adapting the Berkeley Lab method for the type  $k$  client in terms of the elapsed time for the interruption  $h_i$

### Cost Assessment for Emergency Service Intervention (S)

Based on case studies, it was possible to assess the hourly cost associated with emergency service intervention. Costs were attributed the instant a gas conduit was damaged in Montréal. We know that in this particular case, the intervention of first respondents is mandatory and systematic.

### Cost Assessment for Traffic Congestion (C)

Cost assessment for traffic congestion was estimated by the sum of the following costs:

- a) **Costs Related to Time Loss =**  
 number of vehicles in traffic congestion  
 × vehicle occupancy  
 × average wage for region X  
 × elapsed time of traffic congestion in hours
- b) **Costs Related to Fuel Overconsumption =**  
 number of vehicles that took a detour  
 × distance of detour  
 × fuel consumption for 1 km  
 × average fuel price for region X
- c) **Costs Related to Vehicles' Overuse (maintenance and servicing) =**  
 number of vehicles that took a detour  
 × distance of detour  
 × driving costs
- d) **Costs Related to Pollution =**  
 costs related to fuel overconsumption × 6/7

The hypothesis established is that for all damages done on a public road, every vehicle in a traffic congestion must extend his journey by one minute and one kilometre. Also it is hypothesized that there are 5000 vehicles per hour that are potentially affected by the damage. This assessment was taken from a Montréal case study and was adjusted to the municipality's population density that was affected by the damage. According to data from the Origine-Destination survey, vehicle occupancy is 1.2 person per vehicle. For driving costs, we used the CAA-Québec's estimated driving costs. The hypothesis is that the time hindered is equal to the elapsed time of service interruption. This last hypothesis tends to underestimate the costs related to traffic congestion.

### Cost Assessment for Internet Service Interruption (I)

Costs taken into account entailed all economic activities related to Internet service: transactions that cannot take place as well as production reduction or shutdown. Assessment was made using the portion of gross domestic product that is imputable to Internet. According to a study by McKinsey Global Institute, the portion of gross domestic product imputable to Internet is 2.7% (Pélissier du Rausas and al., 2011). It is considered that this cost is evenly distributed over time (methodology for GDP hourly rate by Cromwell & Pearson (2002)). The hypothesis is that for all damages done to telecommunication infrastructures, gas conduits and electrical lines lead to service interruptions. It is considered that there are costs that are related to Internet service interruption. The portion of the affected population is approximated by the number of electricity customers that would be touched by a damaged electrical line. Assessment regarding the proportion of customers affected by the electrical service interruption was made by taken one of the case studies and adjusting it to reflect the population density. The following formula was used to assess the costs related to an Internet service interruption:

$$C_I(h_i) = 0,027 \frac{PIB_t}{(24 \cdot 365)} h_i \left( \frac{1}{\text{Total number of electricity customers}} \right) \times \text{Number of clients from region that were affected by the service interruption}$$

## Result No 4: Total indirect cost assessment regarding damages to underground infrastructures in the province of Quebec; a minimum of 125 million dollars for 2014

To better understand the province's situation, we took the methodology presented in result number 3 and used it to estimate the total annual damage related indirect costs to underground infrastructures that occurred in the province in 2014. Information was taken from a database in which different actors could register information online regarding various events related to underground infrastructures (damages or near damages). The database called DIRT (Damage Information Reporting Tool) or ORDI in French (*Outil de rapport sur les dommages aux infrastructures*) was created in 2003 for the Common Ground Alliance (CGA). This database is managed by Info-Excavation, located in the province of Quebec.

***We have estimated that in 2014, damages to underground infrastructures in Quebec amounted to at least 125 million dollars annually in total indirect costs.***

Damages can be grouped into four categories depending on the type of damaged infrastructure (electric, gas, telecommunication or other (often water lines)). We have estimated that in 2014, damages to underground infrastructures in Quebec **amounted to at least 125 million dollars annually in total indirect costs**. For the province of Quebec, indirect costs are estimated at 0.38% of the GDP for the construction sector.

It is important to note that this figure is very conservative and could be quite higher.

**First, the estimated amount is based on damages recorded on a voluntary basis in the DIRT database. This only gives us a partial picture of what goes on in reality.**

It should be noted that the indirect costs estimation did not take into account aspects such as impact made to the owner's reputation, loss of lives or injuries associated from such damage. Furthermore, there was no data regarding the presence of sensitive sites (hospitals, airports, factories, etc.) near the damaged infrastructures which accounted for nearly 22% of recorded incidents. Such sensitive sites near a damaged infrastructure could only heighten the impact related to a damaged infrastructure and would necessarily entail higher indirect costs.

**Taking into account the limitations set forth, it is very possible that the estimated 125 million dollars for 2014, associated to the total indirect costs related to damaged underground infrastructures in Quebec, is much higher in reality.**

Economic estimation combined to health and safety aspects reflect the importance of prevention. It could translate into systematic locate requests to Info-Excavation before excavating or through the use of best excavation practices.

## Result No 5: Econometric analysis used for identifying the deciding factors behind damages; towards a more effective prevention program

By examining locate requests done prior to a damaged infrastructure, key factors behind damages were identified. This analysis will help develop better targeted activities for a more effective damage prevention program.

To achieve this, a massive data aggregation was performed: the locate requests' database was merged with the reported damages (DIRT) for 2011-2013, using unique identifiers linking locate requests to damages. This process helped compare 1741 damages drawn from DIRT's database and Info-Excavation's locate request database, where approximately 65% of damages were preceded by a locate requests between 2011 and 2013. Then weather data (Temperature, Barometric Pressure, Relative Humidity, Wind Speed, etc.) and seismic data were compiled then integrated to the database to determine their possible effect on the studied damages. The new integrated database contained more than 500,000 observations.

Interesting results were derived by analyzing the new database. Here are just a few of these results:

- Most damages (70 %) occurred in a work area that had 4 infrastructures or less. More than one-fifth of all damages occurred when there was 4 underground infrastructures.
- Excavation work for drainage and water lines make up 36 % of locate requests for which an infrastructure was damaged, and represent only 20 % of the total amount of locate requests. Conversely, street and road excavation work make up 22 % of the total amount of locate requests, but represent 10 % of locate request for which an infrastructure was damaged.
- There is a notable variance in the number of hours of interrupted services, in particular for damages affecting electrical lines and gas conduits. Therefore, it is relevant to explore what characterizes damages that cause an abnormal service interruption (5 hours or more). These damages represent only 3.5 % of total damages but account for 37 % of indirect costs. By using a tree diagram, we can see that damages to electrical infrastructures with very long service interruptions were concentrated within municipalities where population density was fewer than one thousand inhabitants per square kilometre. For damages done to gas conduits, service interruptions of more than 5 hours were caused by excavation work done to drainage and water lines.

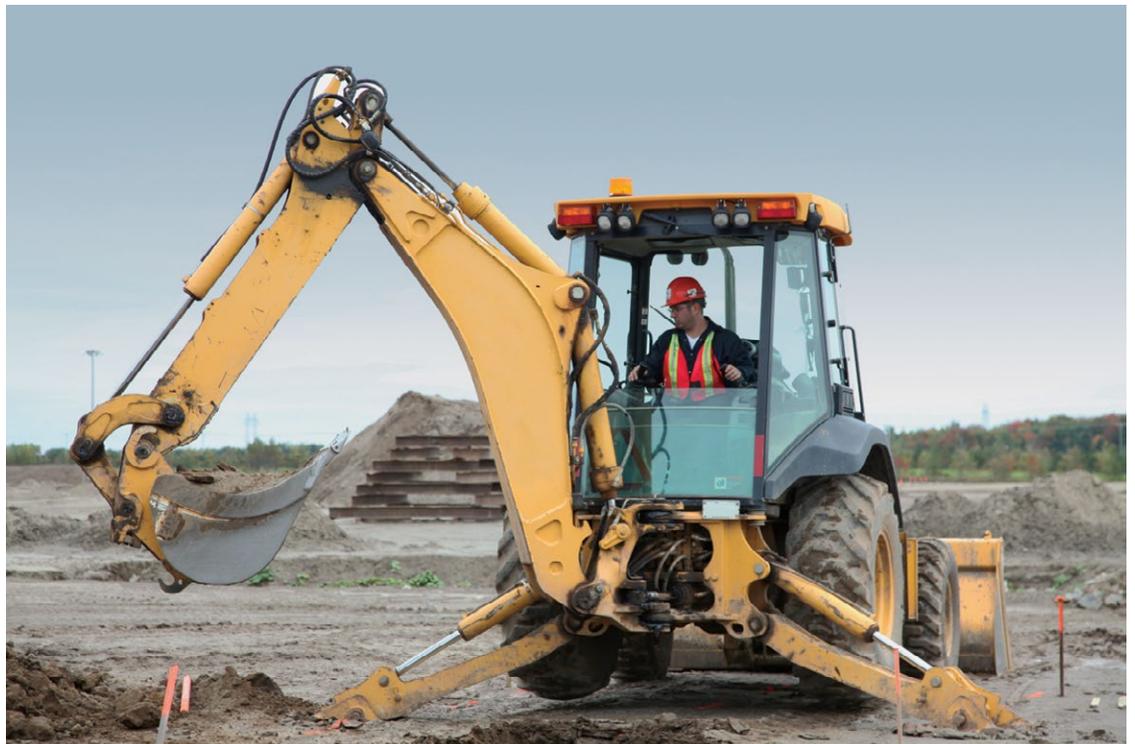


## Conclusion: Importance of damage prevention

The assessment of actual costs related to damaged underground infrastructures in the province of Quebec can:

1. underline the importance of damage prevention and help justify some of the investment aimed at damage prevention and best practices training programs for engineers that are responsible for project planning, for clients (such as municipalities) and contractors;
2. help municipalities and other stakeholders allocate resources targeted at damage prevention and maintenance of high-quality networks;
3. assess the relevance of developing partnerships (e.g. insurance or other emergency stakeholders).

In fact, results from this research will also help stakeholders (municipalities, fire departments, Info-Excavation, company owners of underground infrastructures, contractors, etc.) estimate a project's actual risk, including excavation work; identify options for decreasing the number of damages in Quebec, estimate the related socio-economic costs and appraise the risks associated with jeopardizing the safety of workers and citizens.



## Recommendations

Taking into account the findings and results of our research, the following recommendations were made depending on the actors that intervene when an infrastructure is damaged.

### **Excavation Companies/Individuals Doing Excavation Work**

1. Excavation companies should follow damage prevention training sessions and know the available guides for best excavation practices.
2. Locate requests made to Info-Excavation should be made mandatory throughout the province of Quebec.

### **Owners of Underground Infrastructures**

3. Registering and declaring the location of their network to Info-Excavation should be made mandatory to all owners of underground infrastructures.
4. Owners of underground infrastructures should improve the precision of their data pertaining to the location of their underground network and continue their efforts in identify existing networks.

### **Clients (including municipalities)**

5. Making a locate requests to Info-Excavation should be made mandatory before writing an excavation tender. Initial estimates must be as precise as possible, plans and technical specifications should be more detailed in terms of excavation constraints for bidding companies.
6. Clients should include in their excavation tender a clause where locate requests to Info-Excavation are made mandatory before starting any excavation work.

### **Municipalities**

7. In planning and maintaining their underground infrastructures, municipalities could use the study's results and integrate them in their decision-making process.



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### Report Credentials

de Nathalie Marcellis-Warin, Ingrid Peignier,  
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“Évaluation des coûts socio-économiques reliés aux  
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