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Knowledge into action

Executive Summary

IDENTIFYING OCCUPATIONAL HEALTH AND SAFETY RISKS RELATED TO DAMAGES TO UNDERGROUND INFRASTRUCTURES

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CONTEXTUAL SETTING

Failure to know the precise location of underground infrastructures as well as inadequate excavation methods used during excavation work near underground infrastructures lead to numerous incidents. **In 2017, over 5 damages to underground infrastructures were done on average per day in Quebec** (44% of those involved natural gas or electrical infrastructures) (Damage Report - Info-Excavation 2018). In this regard, it's important to better assess the risks to which workers are exposed so as to tailor efforts in raising awareness and to better target prevention measures. Especially when one realizes that the number of damages has increased through the years (+11% compared to 2016).

Even if in Quebec no deaths have been reported following damages to underground infrastructures, fatal accidents have been reported in other provinces (7 fatalities in Ontario since 2003, 2 fatalities and 6 seriously injured in British Columbia since 2008).

Despite current regulatory changes and damage-related fatalities and injuries throughout Canada, there are but a few analytical studies on risk identification and analysis of occupational health and safety when workers are exposed to damages to underground infrastructures.

OBJECTIVES

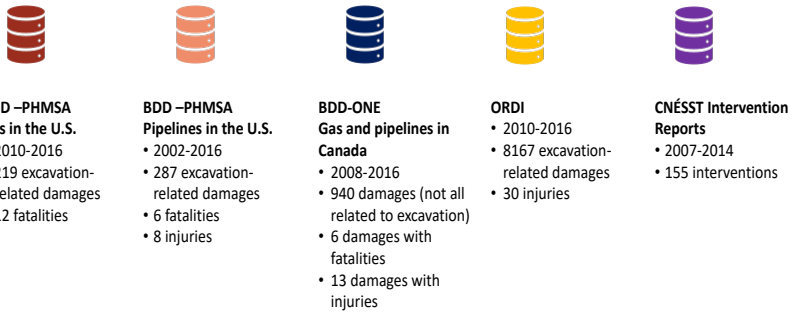
In this regard, it's important to **better assess the risks** to which workers are exposed so as to tailor efforts in raising awareness and to better target prevention measures.
Thus, the research project's objectives were to answer the following questions:

- What are the risks to workers when underground infrastructures are damaged?
- What are the most common consequences?
- What type of equipment was the most often involved in excavation accidents?
- What are the risk factors that increase the likelihood that these risks occur in Canada, and more specifically in Quebec?

METHODOLOGY

Different stages of the research process were adopted:

- **Stage 1: Literature review**
- **Stage 2**: **Statistical analysis of several databases (United States, Canada and Quebec)** related to damages to underground infrastructures to quantify the risks that workers may be injured and identify the causes that have an impact on occupational health and safety.



- **Stage 3: Consultation of different stakeholders affected by damages to underground infrastructures in Quebec** to identify the risk factors that increase the probability of workers being injured or killed when underground infrastructures are damaged and provide specific examples of previous accidents.
  - Interviews were conducted with owners of underground infrastructures, excavating contractors, municipalities and one training school (6 interviews).
  - Focus groups were conducted with owners of underground infrastructures, municipal representatives and excavating contractors (13 participants).
  - An interactive survey was conducted among participants at Info-Excavation's 2017 annual convention held in Saint-Sauveur, Quebec (88 participants).

RESEARCH FINDINGS

1) Identification of hazards faced by workers when an underground infrastructure is damaged

Hazards are quite important and differ depending on the actual type of infrastructure. Hazards associated with every type of infrastructure have been identified (see diagram) as well as a few examples of accidents that have occurred in Quebec or elsewhere in the world.

Workers are exposed to greater risks when gas and electrical conduits are damaged.

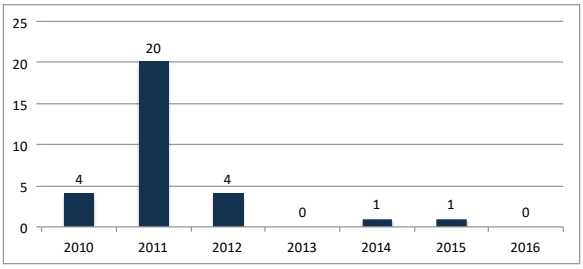
2) Overview of damages to underground infrastructures in Canada and Quebec

In Canada, the study was based on the analysis of the National Energy Board's (NEB) database. The accidents found within this database came mainly from damages done to gas conduits and pipelines over a period of 8 years (between September 2008 and September 2016).

In Canada, 30 injuries and 6 fatalities were compiled during this period (2008-2016). In Quebec, no deaths were compiled when damages occurred on NEB-regulated pipelines. Two fatal damages occurred in Saskatchewan, 2 in British Columbia, 1 in Alberta and 1 in Ontario

Electrical Infrastructures	Gas Conduits	Pipelines	Telecommunications Infrastructure	Water Lines/Sewer Infrastructures
				
Electric shock Electric arc Explosion Fire	Fire Explosion Intoxication	Leak Explosion	Exposure to optical radiation	Pressurized water stream Sewage spill

For Quebec, the study was derived from the DIRT's database (Damage Information Reporting Tool) which is managed by Info-Excavation. DIRT is a self-reporting database. Descriptive statistics are shown in the report. No fatalities were incurred by damages.



Distribution of the number of injuries between 2010 and 2016 (Source: Compilation made by CIRANO from the DIRT database)

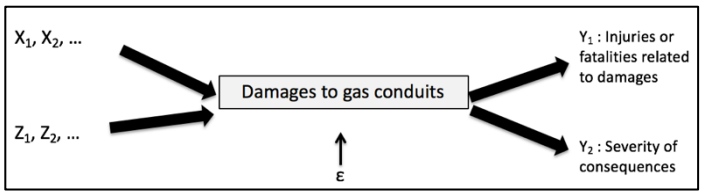
3) Identifying variables that increase probabilities of injuries or fatalities when underground infrastructures are damaged in the United States

Since damages to gas and electrical conduits impact significantly the safety of workers, we based our study on the American PHMSA database (*Pipeline and Hazardous Materials Safety Administration)* which compiles all reported pipeline incidents.

Between 2004 and 2016, 31% of the total of damages done to gas conduits in the United States was incurred by excavation work. Over the same period, 16% of damages incurred by excavation work resulted in injuries or fatalities.

Econometric analysis identifying the main variables that determine fatalities and injuries when underground infrastructures are damaged in the United States.

The process of a damaged gas conduit can be represented as follows:



where

- X_1, X_2, ... are continuous variables (ex: the conduit's diameter, etc.)
- Z_1, Z_2, ... are discrete variables (ex: visible markings, explosion, plastic conduits, conduits located on private land, etc.)
- Y_1 and Y_2 are dependant variables (Y_1 fatalities or injuries related to damages and Y_2 severity of consequences)
- ε represents all unknowns not measured

Multi-criteria analysis technique (binary logistic regression) helped identify four variables that would increase the probability of having injuries or fatalities after a gas conduit is damaged in the United States.

- **Damages that include an explosion** are 18 times more likely to cause fatalities and injuries.
- Damages made to underground infrastructures that have **visible markings** and whose **excavation was done by a contractor** are less likely to cause fatalities and injuries.
- **Damages to conduits with smaller diameters** will most likely be part of the group of damages causing injuries and fatalities. Workers may not necessarily perceive the real hazard behind conduits with smaller diameters and might potentially take fewer precautions.

Two of these variables depend on the nature of such conduits. Whether we are talking about markings or excavating techniques, it's here that the concepts of regulations and training take on their full meaning. In this regard, it would be important to develop other ways of locating conduits than with painted markings. As such, the use of georeferenced maps could be seen as an alternative to painted markings which tend to be erased over time. It would also enable stakeholders to share information more quickly between them.

4) **Extrapolating results for Quebec**

Various results from the analysis of the American PHMSA database cannot be used for statistical projections for Quebec, such as (1) regulations differ between those in Quebec and in the United States, (2) One-Call system is mandatory in the United States, (3) burial depth of gas pipelines are not necessarily identical, (4) the fact that the gas distribution industry in the United States is very different than the one in Quebec (many different owners in the States while Quebec has only two players, though Énergir is a major player) or (5) the fact that there seems to be major differences in terms of the type of actors involved in excavation work (in Quebec, damages are mostly caused by contractors working for municipalities while in the United States, municipalities do their own excavation work).

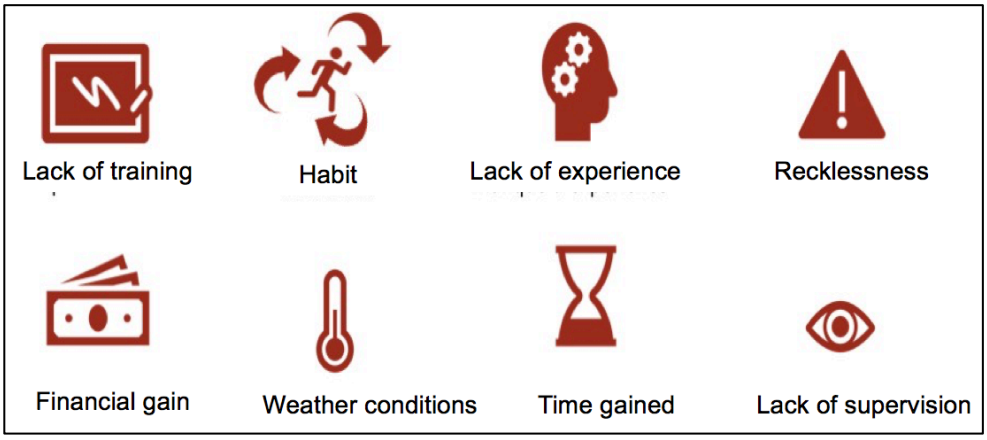
A conclusion can be drawn from this extrapolation (while keeping in mind the limits of such extrapolation): there are more damages in Quebec than in the United States when projected to the length of the underground infrastructures. It seems that the mandatory legislation found in the United States has an impact on this aspect. As such, it could be assumed that if such a legislation was implemented in Quebec, making localization of underground infrastructures compulsory and requiring that companies who own underground infrastructures register their network to a One-Call centre, the number of damage made by excavation work would decrease as well as the number of damages with injuries and fatalities. The fact of introducing a legislation making damage reporting compulsory would enable feedback on work-related accidents in Quebec which is more representative of what really happens therefore, more efficient than damages recorded on a voluntary basis.

Conclusions enhance the importance of a strict regulation, one that would provide a framework to excavation work done in the vicinity of underground infrastructures.

ANALYSIS OF RISK FACTORS

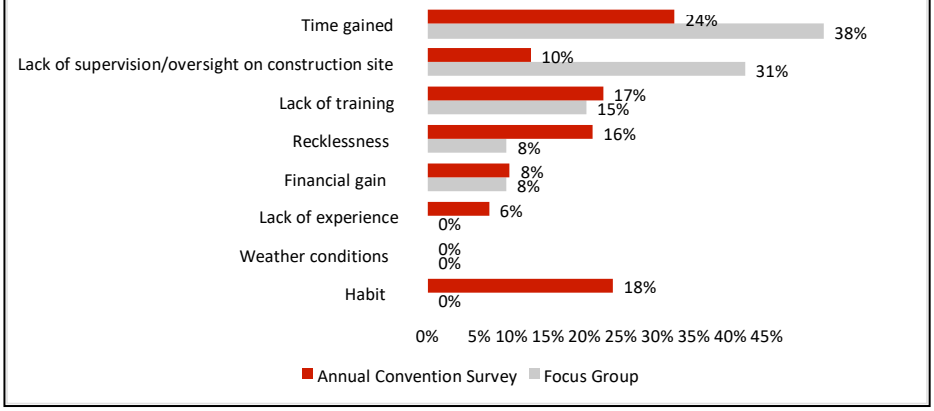
The analysis of various damage-related databases indicate that several causes can lead to accidents. Generally, these causes can be found for all types of infrastructure. How can we then explain these causes? What are the variables that influence

the occurrence of damages, particularly the occurrence of damages with injuries and fatalities? As illustrated below, 8 variables were identified.



To assess perceptions of Quebec stakeholders in terms of the weight of the different risk factors, we conducted two questionnaire-based surveys which include similar questions: (1) one questionnaire aimed particularly at excavating contractors and (2) the other aimed at all the attendees that were present at Info-Excavation's provincial convention (contractors, municipalities, associations, owners of underground infrastructures, etc.).

Comparing the importance of various risk factors between two groups of interviewees that could lead to an accident



The lack of training represents an important risk factor. It's interesting to get an overview of the types of excavation-related training that are currently taken by employees. There are different types of trainings offered by companies and owners of underground infrastructures to their employees. Based on survey results, internal documentation such as working guides are produced in greater numbers by contractors (42% of our survey confirm producing such literature). The attendees at Info-Excavation's annual convention (therefore more diverse actors) use more training sessions internally with documentation. Employees also receive external trainings, such as free training sessions offered by Info-Excavation or meetings with school boards or with APSAM representatives.

Should training be developed and provided to employees, in what format would you like it to be given? This was the last question asked to all participants in both surveys. An overwhelming majority of respondents preferred worksite trainings which would provide a proper understanding of the risks they may face during excavation work. A mobile application dedicated to self-learning was mentioned as a second interactive solution by contractors, owners of underground infrastructures and municipalities. Meanwhile, classroom trainings are viewed as a complement to theoretical learning.

CONCLUSIONS

Results from the study provided an important insight on the development of knowledge related to the dangers faced by workers exposed to damages to underground infrastructures.

Identifying variables that increase probabilities of injuries or fatalities when underground infrastructures are damaged will help focus prevention efforts where they are needed.

All these elements can be integrated in the damage prevention decision process either directly by excavation companies, public authorities or organizations in connection with the issue.

How can the number of injuries or fatalities be reduced during excavation work?

Instilling accountability to the entire chain: owners of underground infrastructures, excavating contractors, municipalities, construction workers.

Focusing on training: review the training formats, implement a monitoring process, motivate workers to take part in such training.

Reassess localization procedures

Propose **regulatory changes that would make it compulsory to locate underground infrastructures** and make the use of a framework mandatory for excavation work done in the vicinity of underground infrastructures.

It is clear that communication, training and awareness efforts must be maintained while advocating the adoption of a clear legislation that would provide a strict framework to excavation work.

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Allier savoir et décision

We would like to thank Info-Excavation and their partners for their collaboration in our study.

REPORT CREDENTIALS

De Marcellis-Warin, Nathalie and Ingrid Peignier. 2018. « Identification des risques liés aux bris d'infrastructures souterraines pour la santé et la sécurité des travailleurs », CIRANO Research Report, 2018RP10

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