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CONFÉRENCE

# Évaluation des galerie multiréseaux comme option économiquement viable pour Montréal

## *Feasibility Analysis of Multi-purpose Utility Tunnels in Montreal*


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PALAIS DES CONGRÈS DE MONTRÉAL
INFRA 2015 – 5 DÉCEMBRE 2017

# Feasibility Analysis of Multi-purpose Utility Tunnels in Montreal

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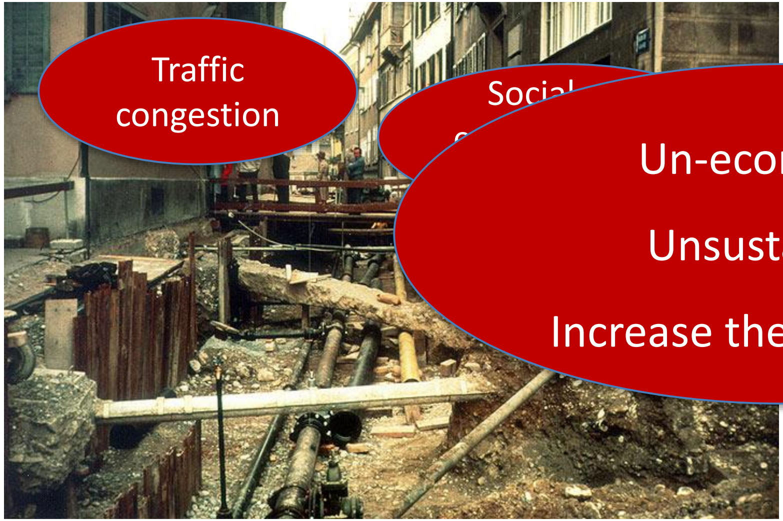
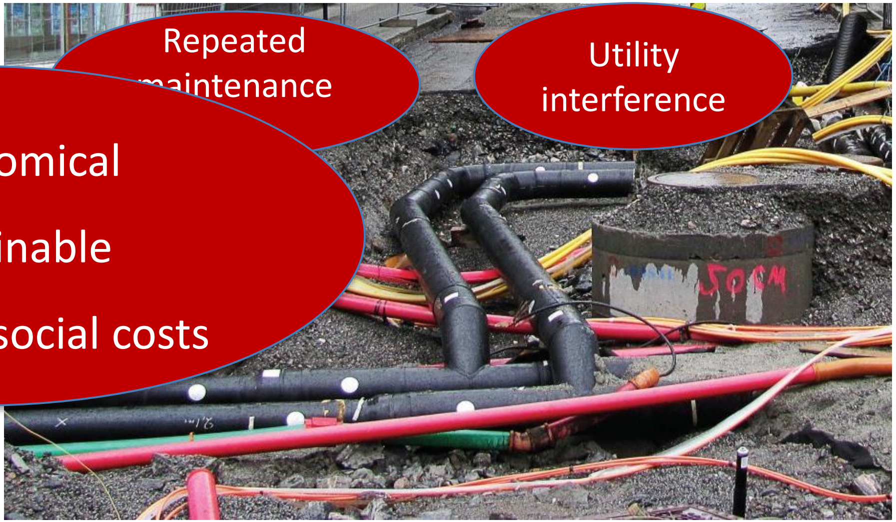
## Introduction of multi-purpose utility tunnels (MUTs): Buried utilities




https://www.youtube.com/watch?v=Wa_WF061Wig&ab_channel=liq9994; http://www.unitracc.com/know-how/fachbuecher/rehabilitation-and-maintenance-of-drains-and-sewers/rehabilitation/replacement-en/utility-tunnel-en

http://www.themunicipal.com/2018/03/communicating-vital-is-key-to-handling-abandoned-utilities/

## Introduction of multi-purpose utility tunnels (MUTs)


Singapore

https://www.ura.gov.sg/sales/MarinaUnionSt/MV-large%20floor%20plate.html

Prague, Czech Republic

https://en.wikipedia.org/wiki/Utility_tunnel

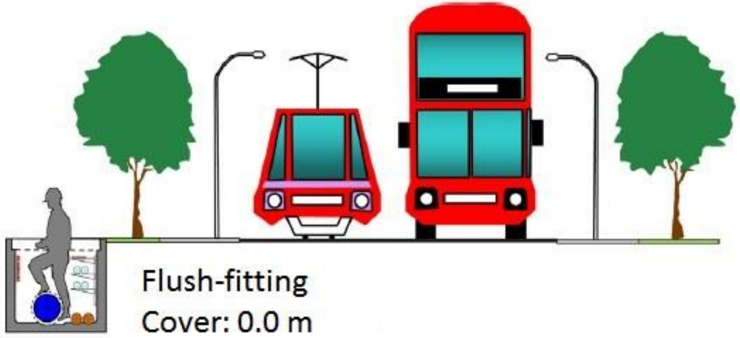
# Introduction of multi-purpose utility tunnels (MUTs)

## MUT Definition

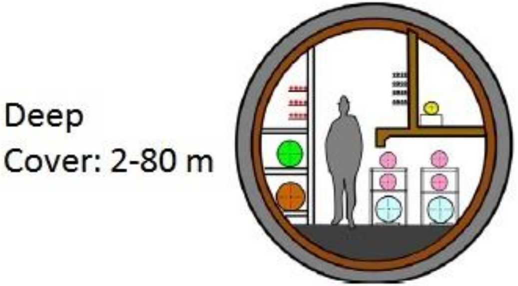
An underground utilidor containing one or more utility systems, permitting the installation, maintenance, and removal of a utility system without making street cuts or excavations.

(Canto-Perello and Curiel-Esparza, 2013)

# MUT classification based on depth

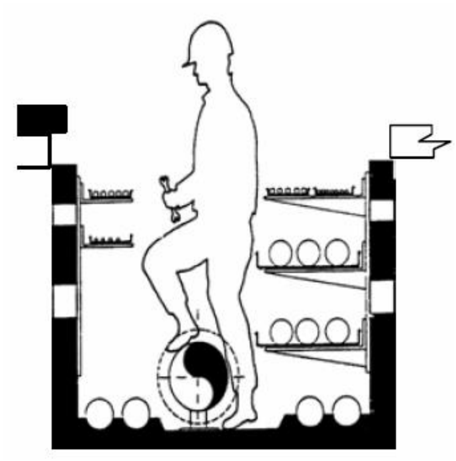




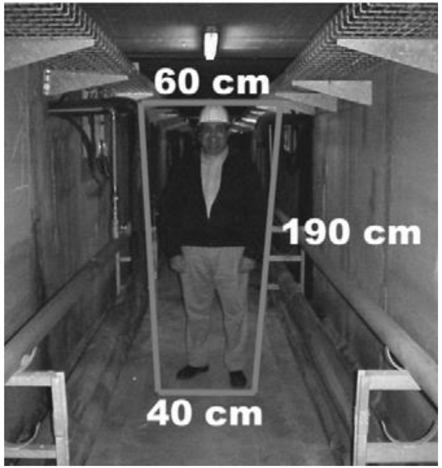



(Rogers and Hunt, 2006; Hunt and Rogers, 2014)

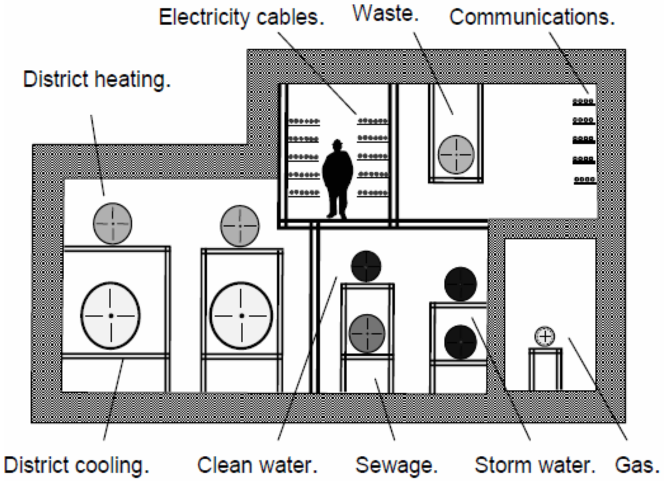
## MUT classification based on types



Searchable




Visitable




Compartmentalized

(Rogers and Hunt, 2006)

## MUT constructions methods

- Cast-in-place concrete
  - Simple with high flexibility in execution
  - Longer duration
- Prefabricated concrete/fiber glass segments
  - Faster execution
  - Higher quality
  - Transportation of large segments issues
  - Possible weakness in joints

# Feasibility Analysis of Multi-purpose Utility Tunnels in Montreal

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- Introduction of multi-purpose utility tunnels (MUTs)
- MUT advantages and disadvantages
- MUT development in the world
- MUT planning
- Multi-criteria decision making
- Conclusions

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## MUT advantages and disadvantages

- Advantages

- Significant reduction of repeated excavations for maintenance and repair;
- Improved inspection and maintenance of utilities;
- Minimization of damage and corrosion of utilities;
- Decreased traffic congestion;
- Improved health and safety and less impact on the environment.

(Cano-Hurtado & Canto-Perello, 1999; Hunt & Rogers, 2006; Laistner, 1997; Canto-Perello & Curiel-Esparza, 2013; Clé de Sol, 2005; Hunt et al., 2014; Canto Perello, J. & Curiel Esparza, 2003; Gilchrist & Allouche, 2005; Ormsby, 2009; CERIU, 2010; Najafi & Kim, 2004)

## MUT advantages and disadvantages

- Disadvantages

- High initial cost;
- Compatibility and safety issues between utilities (e.g. gas and electricity)
- Security risks related to human attacks;
- Complicated coordination of utility providers.

(Cano-Hurtado & Canto-Perello, 1999; Hunt & Rogers, 2006; Hunt & Rogers, 2005; Canto-Perello & Curiel-Esparza, 2013; Canto-Perello et al., 2009)

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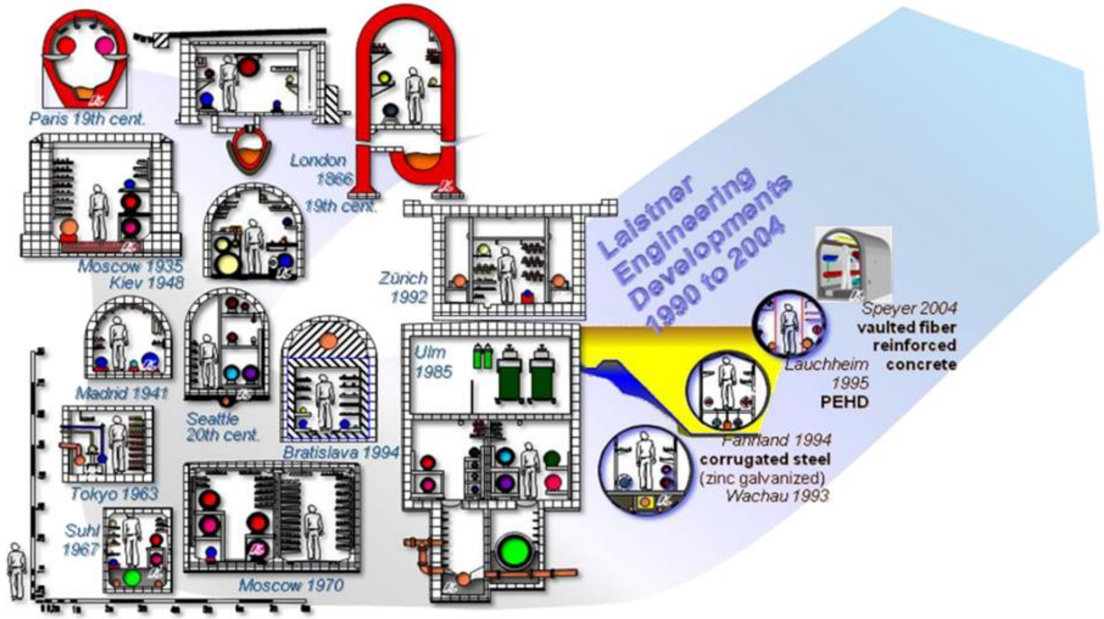
## MUT development in the world




MUTs in the world from 1866

(Laistners A. & Laistner H., 2012)

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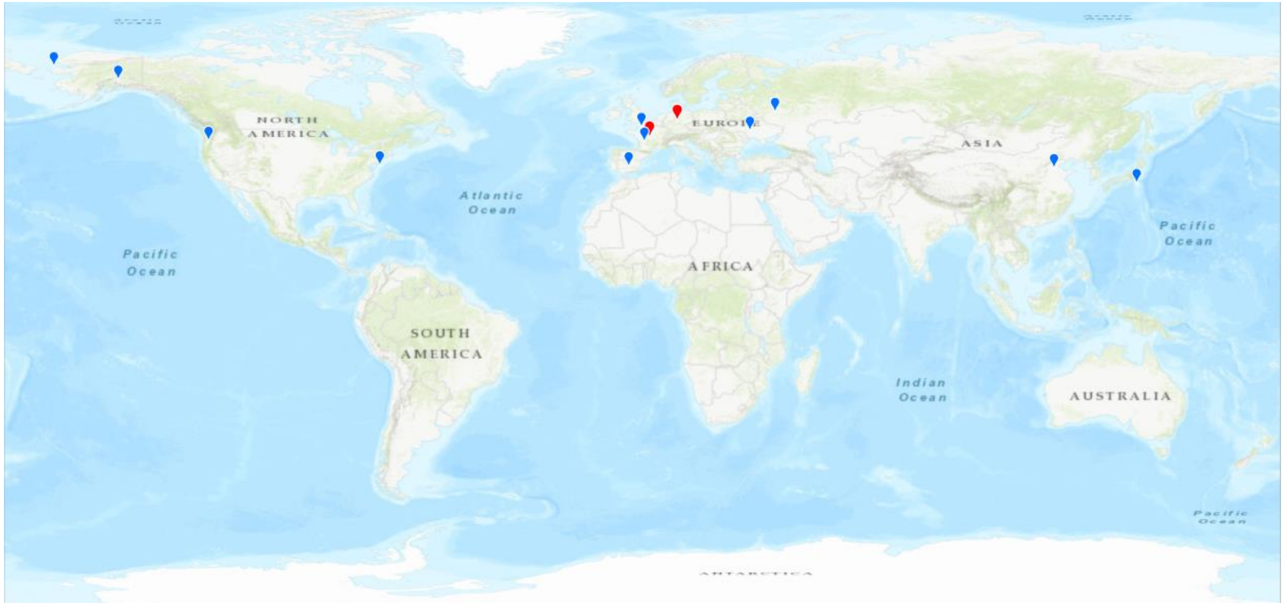
## MUTs constructed in the 19th century

# Feasibility Analysis of Multi-purpose Utility Tunnels in Montreal

## MUTs Construction from 1921 to 1960




1800s (3)

1921-1960 (11)

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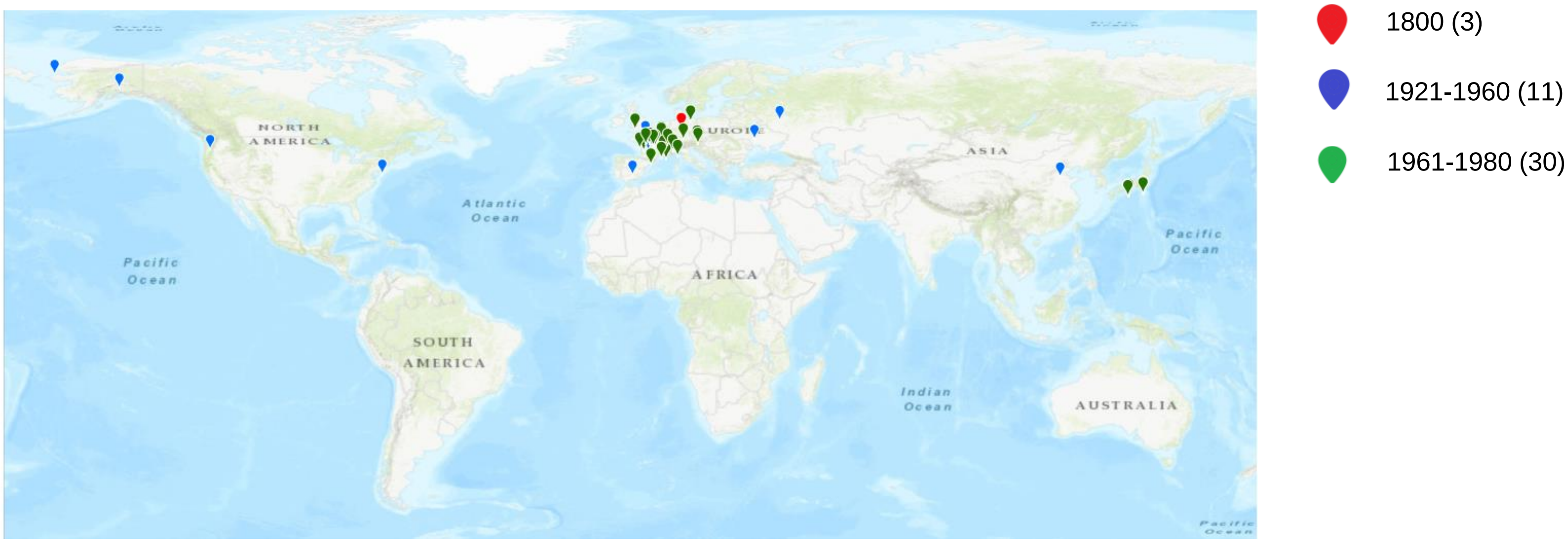
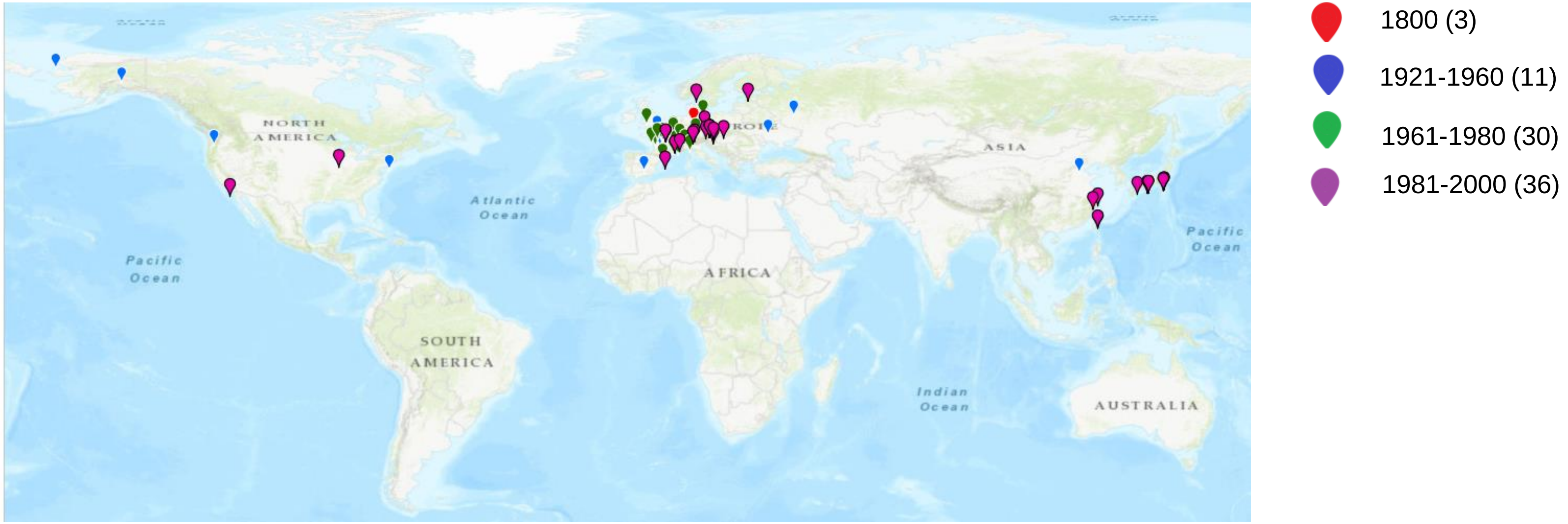
## MUTs Construction from 1961 to 1980



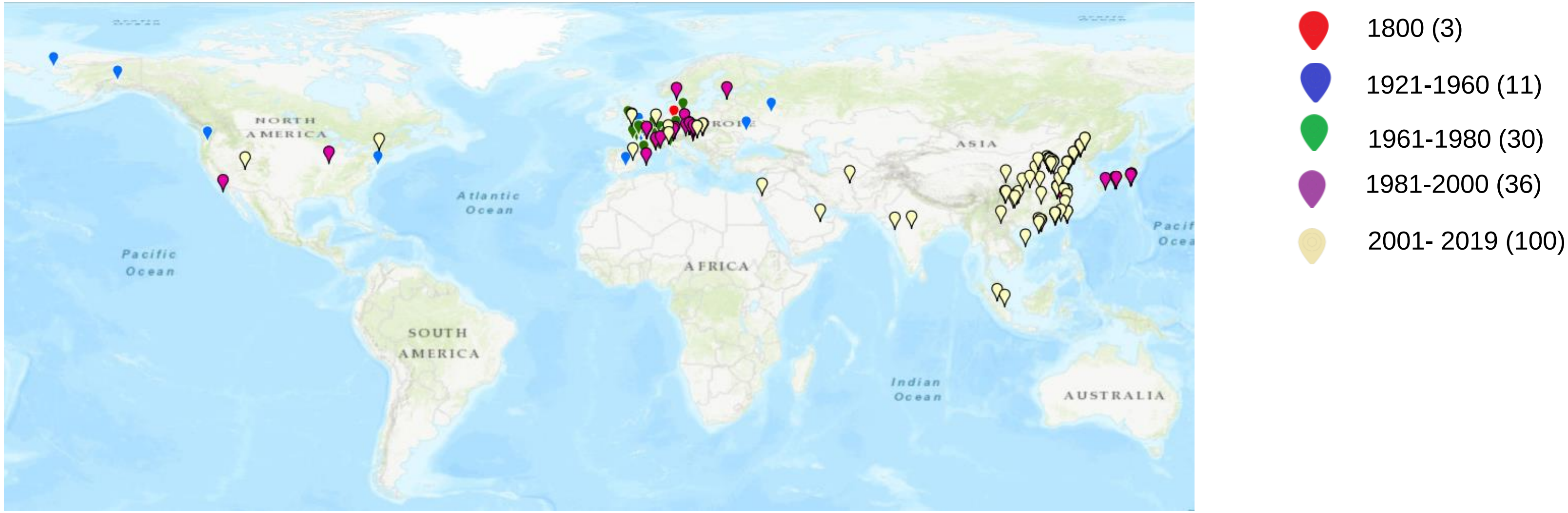

- 15 in France and 8 in Japan.
- Countries including Belgium , Czech Republic, Switzerland, Germany and the UK also constructed MUTs .

## MUTs Construction from 1981 to 2000




- Majority of which was built in Czech Republic(33%), Japan Constructed about 30%.

## MUTs Construction from 2001 to 2019




- Currently about 100 MUTs are either under construction or have been commissioned, 80% are in China.
- Taiwan is actively involved in the construction of MUTs but there is limited data on the MUTs.
- Countries like Iran, Qatar, Malaysia, UK,  Israel, etc. are also involved in the construction of MUTs.

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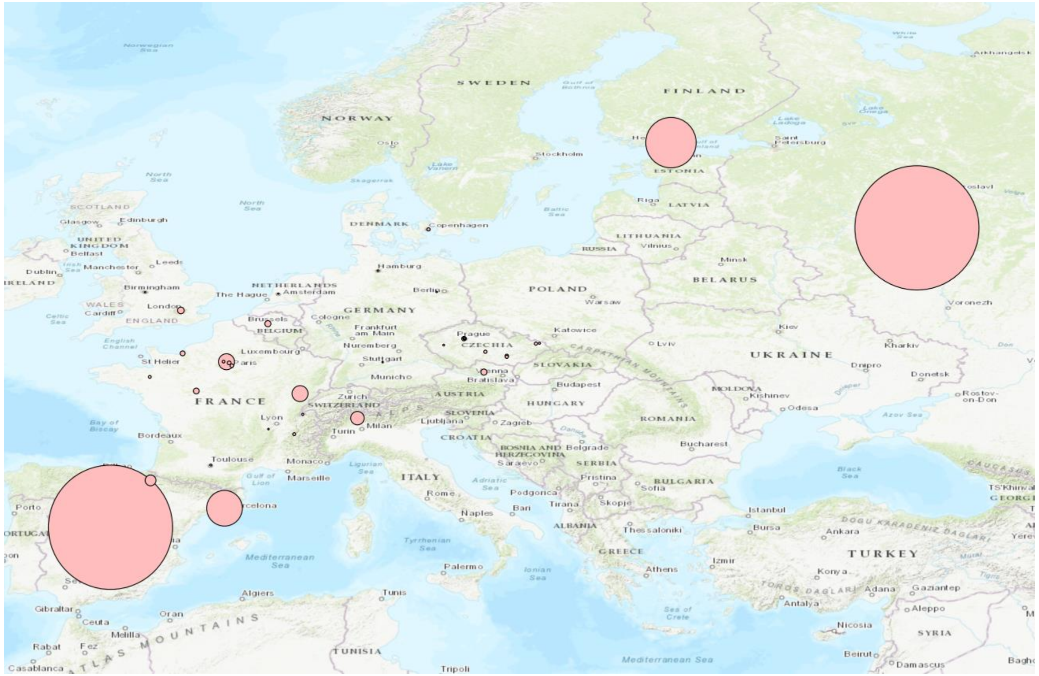
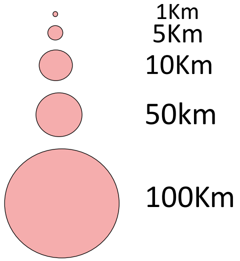
## Varying MUT lengths in Europe



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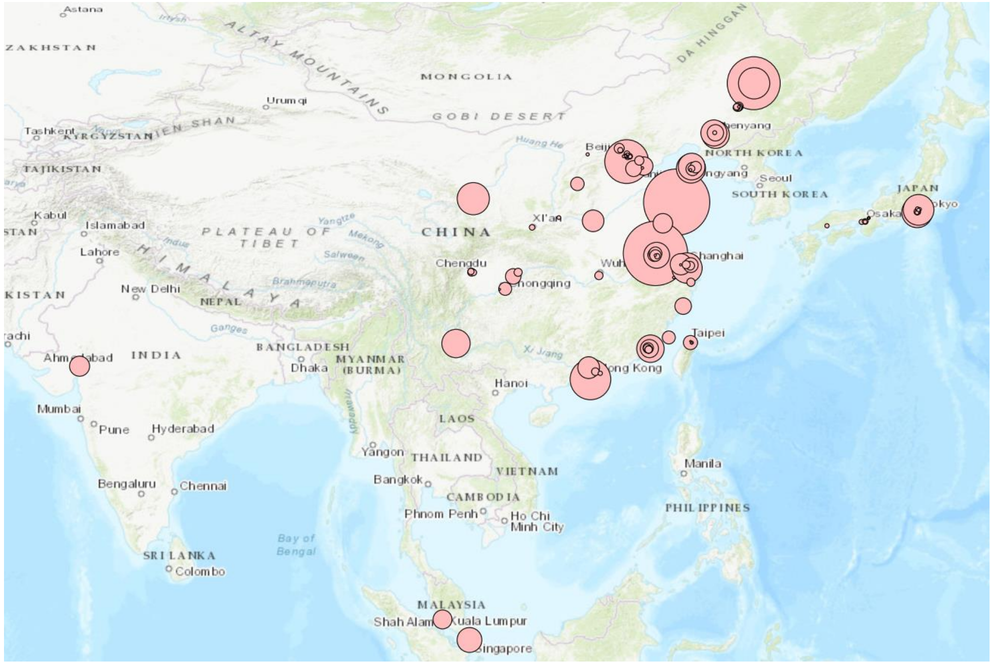
## Varying MUT lengths in Asia




1km
5Km
10Km
20Km
30km
50Km

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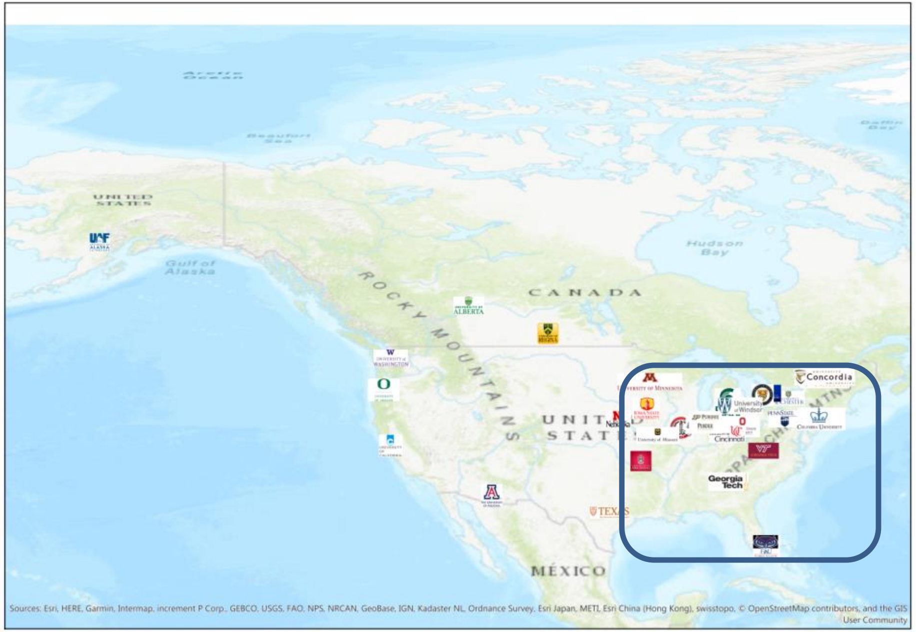
## MUTs in North America





Majority of the MUTs found in North America are situated on University campuses, Hospitals, Military installations and Private establishments like Disney world in Florida.

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- Multi-criteria decision making
- Conclusions

## MUT planning

- MUT planning is a key factor of urban underground space (UUS) planning which is an important part of urban planning. (Canto-Perello et al., 2016)
- Safety and security issues increase the complexity of MUT planning. (Canto-Perello et al., 2016)
- MUT planning includes **MUT location selection** and **utility type selection**.

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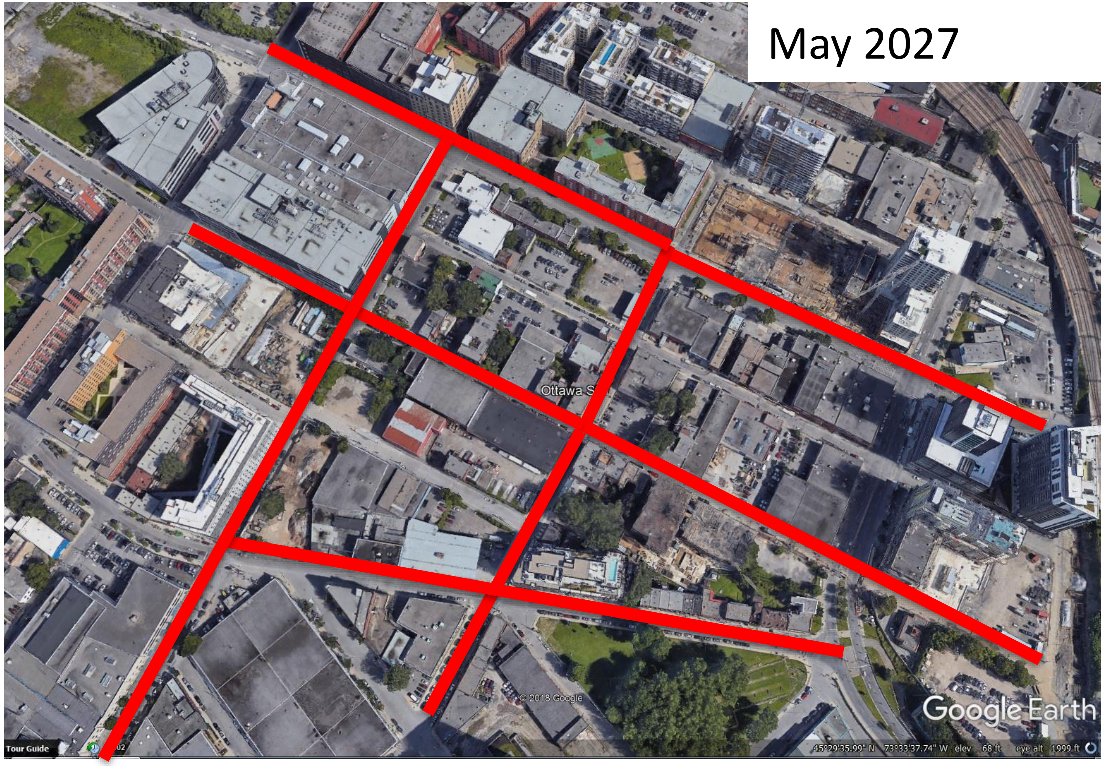
May 2027




Long-term plan for MUT construction

## MUT location selection

- High density areas such as commercial areas, high density underground areas (e.g. land use, population density);
- Areas with high traffic volume and high utility density;
- Areas with future repair and construction projects (e.g. repairs of roads, utilities, new metro lines)

(Peng et al., 2018)

## MUT location selection: 8 main criteria

- Annual Average Daily Traffic (AADT)
- Road class
- Utility density
- Number of expected excavations for utility repair activities
- Underground development projects
- Population density
- Land use
- Near to public facilities/high-rise buildings

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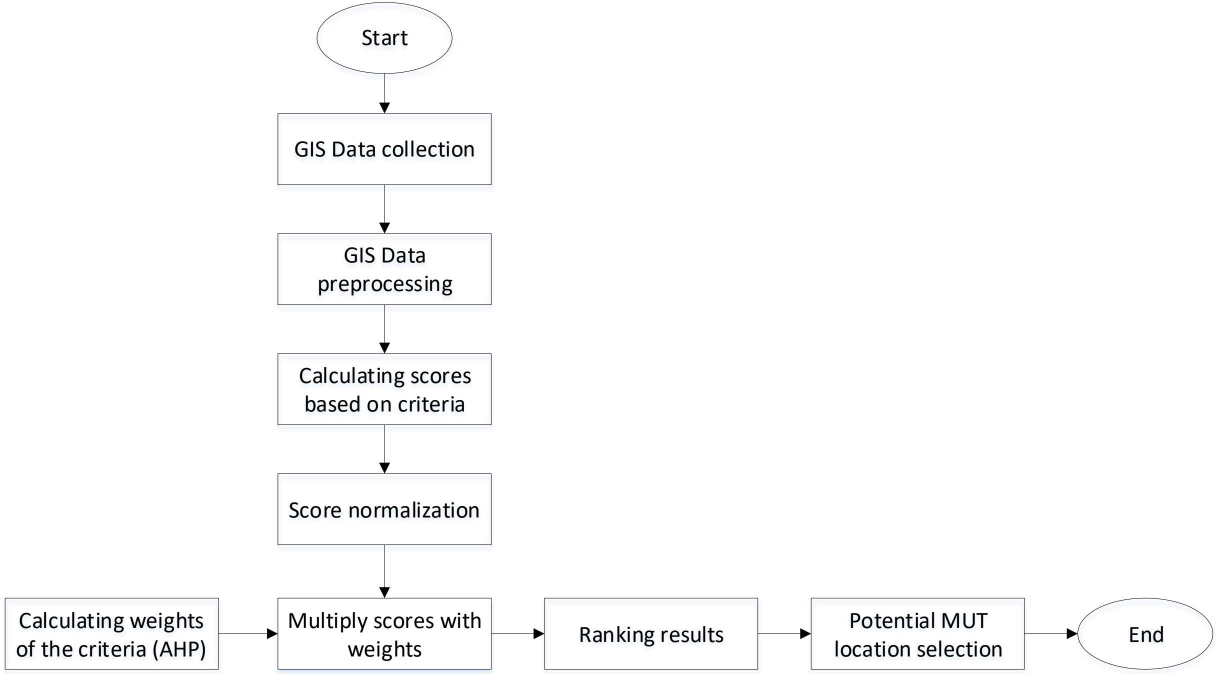
# Multi-criteria decision making for MUT location selection



## Multi-criteria decision making: Data scoring and normalization

- All criteria must be scored using the same scale (e.g. 0-1).
- Different criteria are normalized differently.
- Criteria with **non numeric attributes** are assigned scores based on relevance.
- Attributes with higher relevance are given high scores and vice versa.
    - Road class
    - Underground development projects
    - Land use

## Multi-criteria decision making: Data scoring and normalization

- Road class criterion is normalized based on a scale of 0-1.

| Road class | Score |
|---|---|
| class 0 – Rues locales (Local roads) | 0.5 |
| class 1 – Certaines voies piétonnières (Pedestrian routes) | 0.2 |
| class 2 – Places d’affaire (Business places) | 0.6 |
| class 3 – Quai (Wharf) | 0.1 |
| class 4 – Privée (Private) | 0.1 |
| class 5 – Collectrices (Collectors) | 0.8 |
| class 6 – Artères secondaires (Secondary arteries) | 0.8 |
| class 7 – Artères principals (Main arteries) | 1.0 |
| class 8 – Autoroutes (Highways) | 1.0 |
| class 9 – Rue projetée (Projected streets) | 0.3 |

## Multi-criteria decision making: Data scoring and normalization

- Underground development projects criterion is scored as 0 or 1.

| Underground development projects | Scores |
|---|---|
| Yes | 1 |
| No | 0 |

## Multi-criteria decision making: Data scoring and normalization

- Land use criterion is normalized based on a scale of 0-1.

| Land use | Scores |
|---|---|
| Activites Diversifiees (Diversified activities) | 1.0 |
| Agricole (Agricultural) | 0.1 |
| Conservation (Preservation) | 0.1 |
| Emplois (Employment) | 1.0 |
| Infrastructure (Infrastructure) | 0.7 |
| Institution (Institution) | 0.9 |
| Mixe (Mix) | 0.8 |
| Parc (Park) | 0.1 |
| Religieux (Religious) | 0.2 |
| Residential (Residential) | 0.6 |

## Multi-criteria decision making: Data scoring and normalization

- Criteria with **numeric attribute values**
  - AADT
  - Utility density
  - Number of expected excavations for utility repair activities
  - Population density
  - Near to public facilities/high-rise buildings

are normalized using

$$Normalized\ score = \frac{X_i - X_{min}}{X_{max} - X_{min}} \qquad \text{Equation 1}$$

## Multi-criteria decision making: Data scoring and normalization

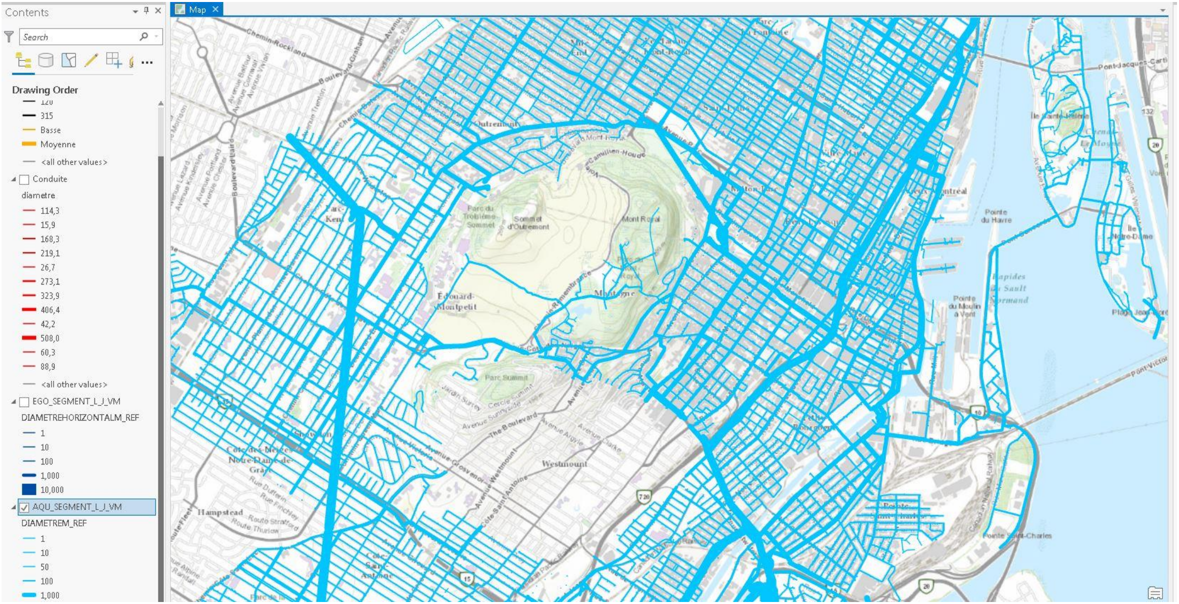
- Utility density (UD)
  - Total number of utilities
  - Level of utilities

$$UD = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} L_{ij} LS_{ij}}{l_r}$$

UD = Utility density of one road segment;
i=Utility type in the road segment (1 to n);
j=Number of utility levels in one utility type (1 to m);
$L_{ij}$ =Length of different utility shapes;
$LS_{ij}$ =Level score (based on diameter of pipes etc.);
$l_r$=Length of the road segment.

## Multi-criteria decision making: Data scoring and normalization

- Utility density: Water network (Thickness based on pipe diameter)



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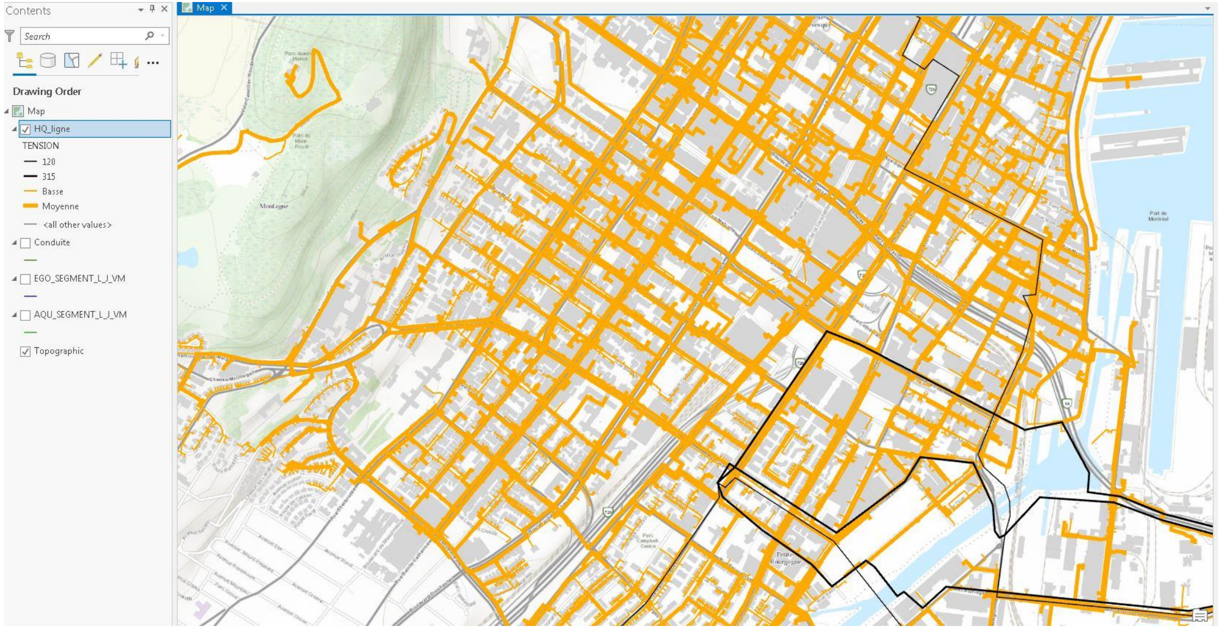
## Multi-criteria decision making: Data scoring and normalization

- Utility density: Electricity network (Thickness based on voltage)



## Multi-criteria decision making: Data scoring and normalization

- Number of expected excavations for utility repair activities (NE)
- For now, use breakage rate to predict this criterion.
- Breakage rate: number of breakage per km per year.

$$\mathrm{NE} = \sum_{i=1}^{n}\sum_{j=1}^{m} BR_{ij}LS_{ij}$$

NE =Number of expected excavations for utility repair activities for one road segment;
i=Utility type in the road segment (1 to n);
j=Utility segment for each utility type i (1 to m);
BR=Breakage rate
LS=Level score (based on diameter of pipes etc.);

## Multi-criteria decision making: Data scoring and normalization

- Population density $= \frac{Population}{Area}$
- Near to public facilities/high-rise buildings is represented by the number of public facilities/high-rise buildings that are within a predefined distance from the road segments (e.g. 500 m).

## Multi-criteria decision making: Analytic hierarchy process (AHP)

Using AHP to define weights of the criteria:

- Creating a hierarchical model which consists of the goal, criteria, sub-criteria and alternatives
- Building a pairwise comparison matrix for the criteria
- Deriving the scale of weights and checking the consistency
- Ranking the options (R. W. Saaty, 1987; T. L. Saaty, 2008)

## Multi-criteria decision making: Analytic hierarchy process (AHP)

| Value of importance | Explanation |
|---|---|
| 1 | Two criteria are equal |
| 3 | One criterion is slightly more important than the other |
| 5 | One criterion is moderately more important than the other |
| 7 | One criterion is very strongly more important than the other |
| 9 | One criterion is extremely more important than the other |

## Multi-criteria decision making: Analytic hierarchy process (AHP)

*Importance of criteria (A1-A10)*

| | | | | |
|---|---|---|---|---|
| Priority #1 | A1 | A3 | A4 | |
| Priority #2 | A5 | | | |
| Priority #3 | A2 | A6 | | |
| Priority #4 | A7 | A8 | A9 | A10 |

AHP →

*Weights*

W1=W3=W4=0.2463

W5=0.0863

W2=W6=0.0457

W7=W8=W9=W10=0.0209

## Multi-criteria decision making

- The total score of each road segment:

$$S = \sum_{i=1}^{n} w_i x_i$$

*S*: total evaluation score;

$w_i$: weight of evaluation criterion *i* ($\sum_1^n \mathrm{w_i} = 1$);

$x_i$: value of evaluation criterion *i* ($0< \mathrm{x_i} \leq 1$);

*n*: number of criteria.

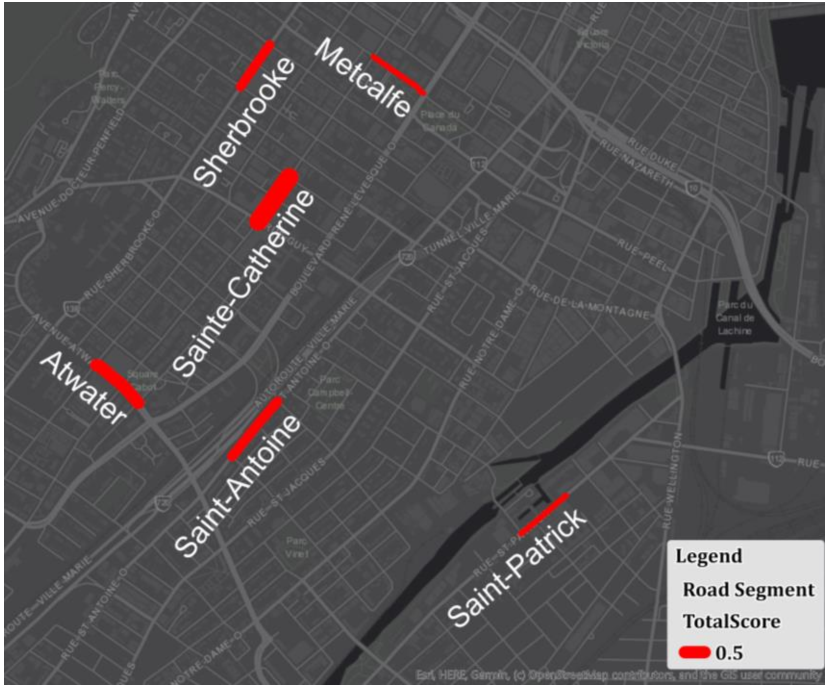
- The road segments with higher scores are chosen.

# Feasibility Analysis of Multi-purpose Utility Tunnels in Montreal

## Multi-criteria decision making: Case study

| | Weights (%) | Sainte-Catherine | Sherbrooke | Atwater | Metcalfe | Saint-Antoine | Saint-Patrick |
|---|---|---|---|---|---|---|---|
| Length (m) | | 205.48 | 196.49 | 217.90 | 239.32 | 272.85 | 226.67 |
| AADT | 8.01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Road class | 7.05 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Utility density | 24.46 | 0.76 | 1.00 | 0.96 | 0.35 | 0.58 | 0.32 |
| Number of excavations | 16.24 | 1.00 | 0 | 0 | 0 | 0.53 | 0 |
| Underground development project | 18.63 | 1 | 0 | 0 | 0 | 0 | 0 |
| Population density | 9.76 | 0.26 | 0.42 | 1.00 | 0.15 | 0.64 | 0.28 |
| Land use | 8.40 | 0.83 | 0.80 | 0.80 | 0.80 | 0.60 | 0.80 |
| Near to public facilities/high-rise buildings | 7.45 | 1.00 | 0 | 1.00 | 0 | 0 | 0 |
| Total score | | 0.76 | 0.41 | 0.53 | 0.22 | 0.40 | 0.23 |

## Multi-criteria decision making: Case study



## Conclusions

- MUT construction decreased in European countries in recent years;
- MUTs have a rapid development in Asian countries, especially in China;
- Although the initial cost is high, there is a high potential of MUT development that can contribute to the development of smarter, more sustainable and resilient cities;
- The general MCDM method for MUT location selection based on GIS spatial analysis is feasible.

# Thank you!

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