Smart City Course

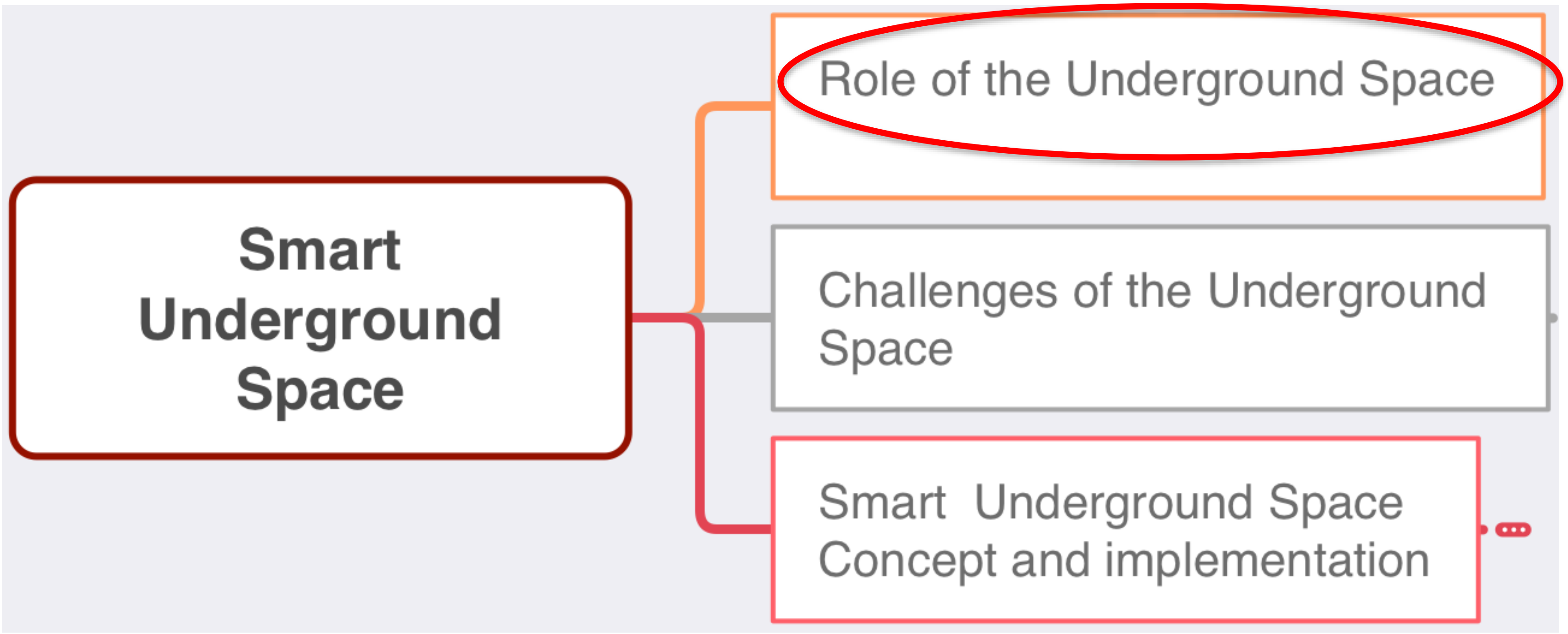
Lecture 10 : Smart Underground Space

Professor Isam SHAHROUR

Tongji University, Shanghai, June 2021

Outline

Part 1



Part 2 Smart Utility Tunnel

Underground Space has a vital role in urban areas

It hosts

Urban Utilities

Transport Infrastructures

Underground Space has a vital role in urban areas

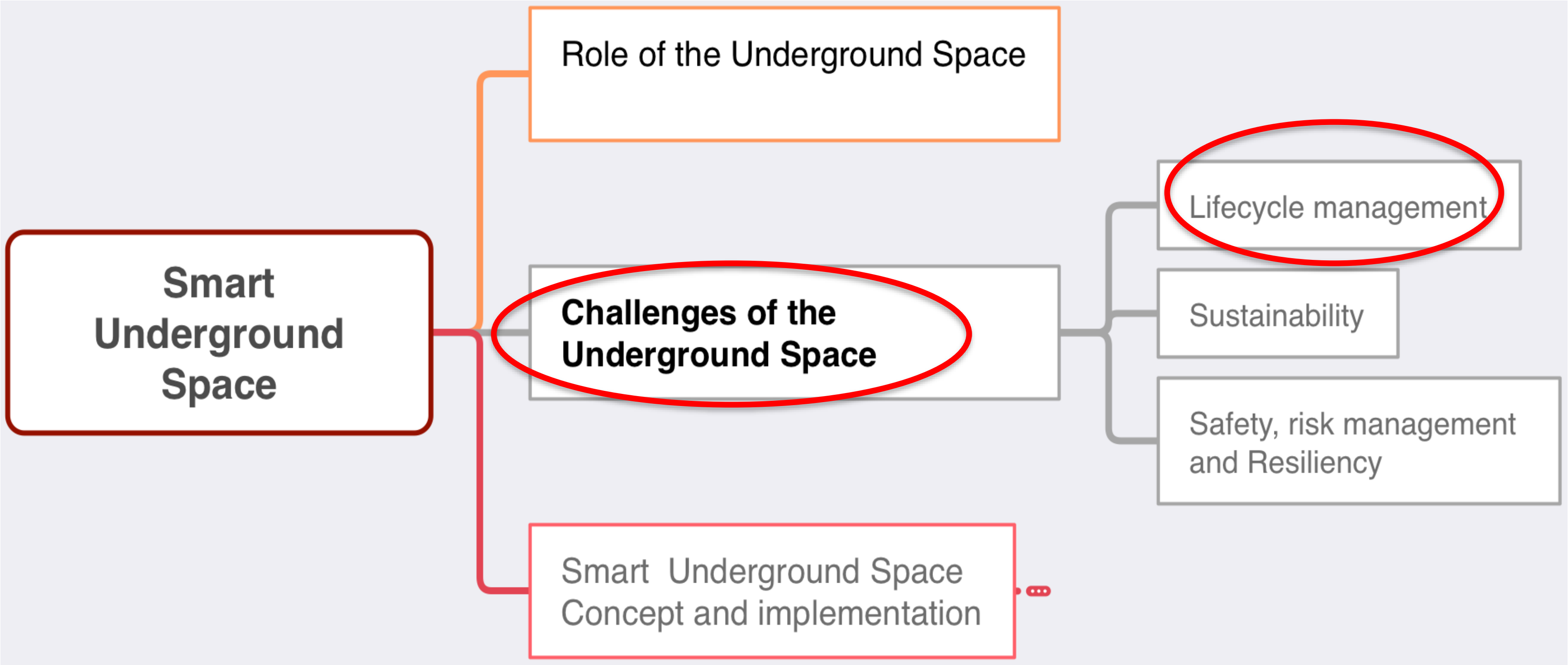
It hosts

Water and
Energy facilities

Commercial and
activities Centers

Underground projects - 2016

Outline



Smart Underground Space
Role of the Underground Space
Challenges of the Underground Space
Lifecycle management
Sustainability
Safety, risk management and Resiliency
Smart Underground Space Concept and implementation

1) Lifecycle management

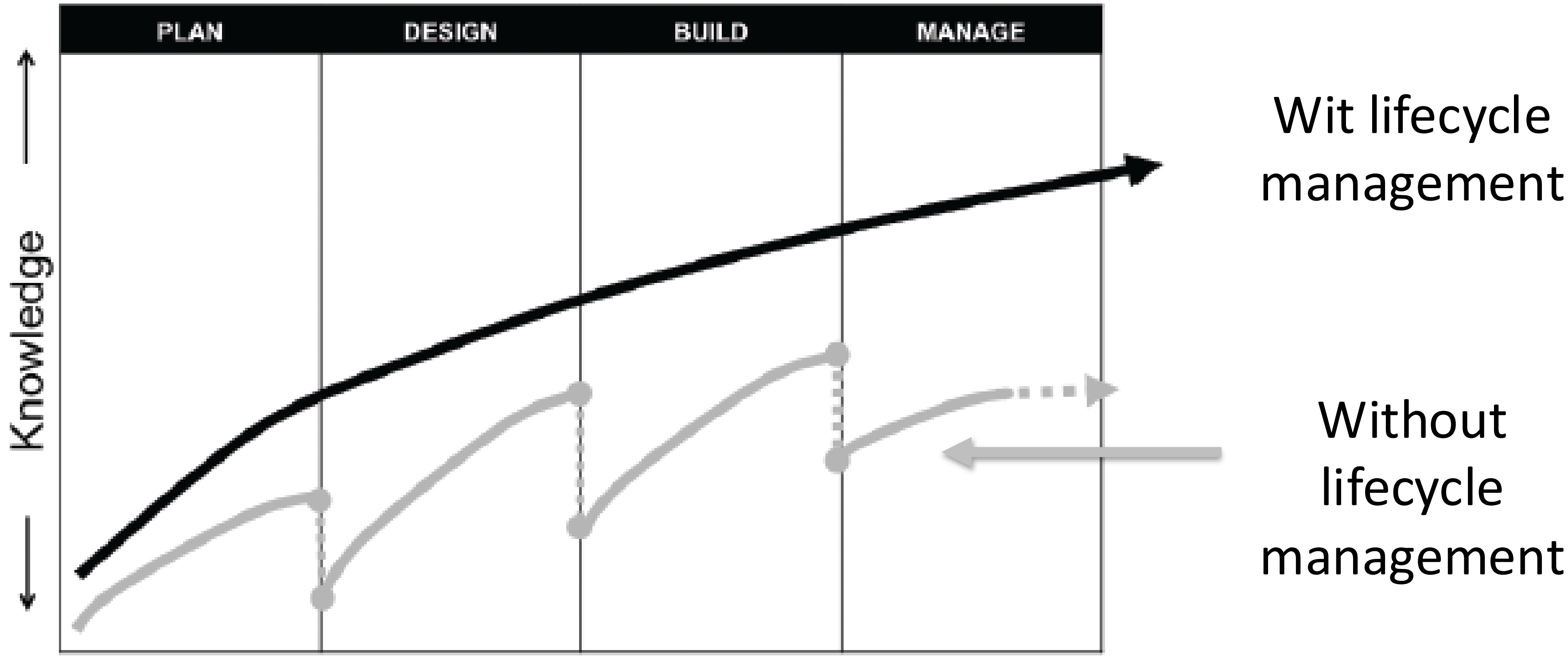
4 major and complex stages for the lifecycle of the underground space

Planning → Design → Construction → Exploitation

2 Questions :

Q1: How to take into consideration these stages in the global cost ?

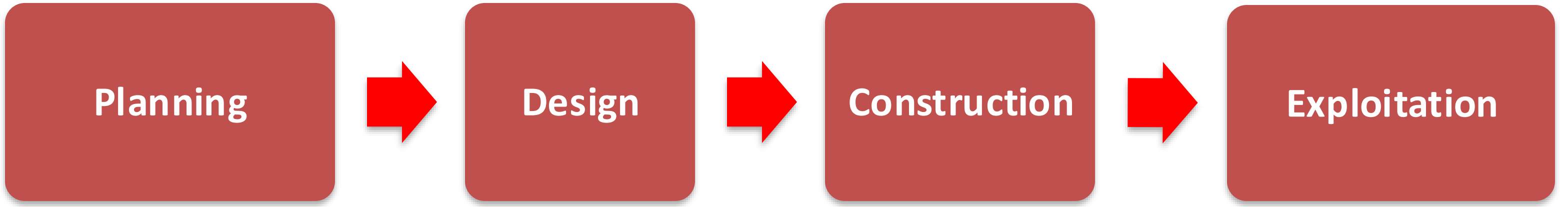
Q2: How to ensure data and information transmission over the lifecycle ?



BIM FOR INFRASTRUCTURE, AUTODESK

Lifecycle management

Each stage is based on data and generates new data



- Urban environment
- Subsoil (preliminary studies and investigations)

Lifecycle management

Each stage is based on data and generates new data

Planning → Design → Construction → Exploitation

- Urban environment
- Subsoil (preliminary studies and investigations)

- Advanced soil exploration (geophysics, field exploration, laboratory tests, hydraulic)
- Design of structural elements as well as technical equipment
- Output (AutoCad, BIM, plans, charts,..)

Lifecycle management

Each stage is based on data and generates new data

Planning → Design → Construction → Exploitation

- Urban environment
- Subsoil (preliminary studies and investigations)

- Advanced soil exploration (geophysics, field exploration, laboratory tests, hydraulic)
- Output (AutoCad, BIM, plans, charts,..)

- Data from soil excavation
- Soil treatment
- Structures built elements
- Soil and Structure movement
- Hydraulic parameters
- Technical equipment

Lifecycle management

Each stage is based on data and generates new data

Planning → **Design** → **Construction** → **Exploitation**

- Urban environment
- Subsoil (preliminary studies and investigations)

- Advanced soil exploration (geophysics, field exploration, laboratory tests, hydraulic)
- Structural elements
- Underground equipment (electrical, mechanical,..)

- Additional soil data from
- Structural elements
- Soil and structure movement
- Equipment

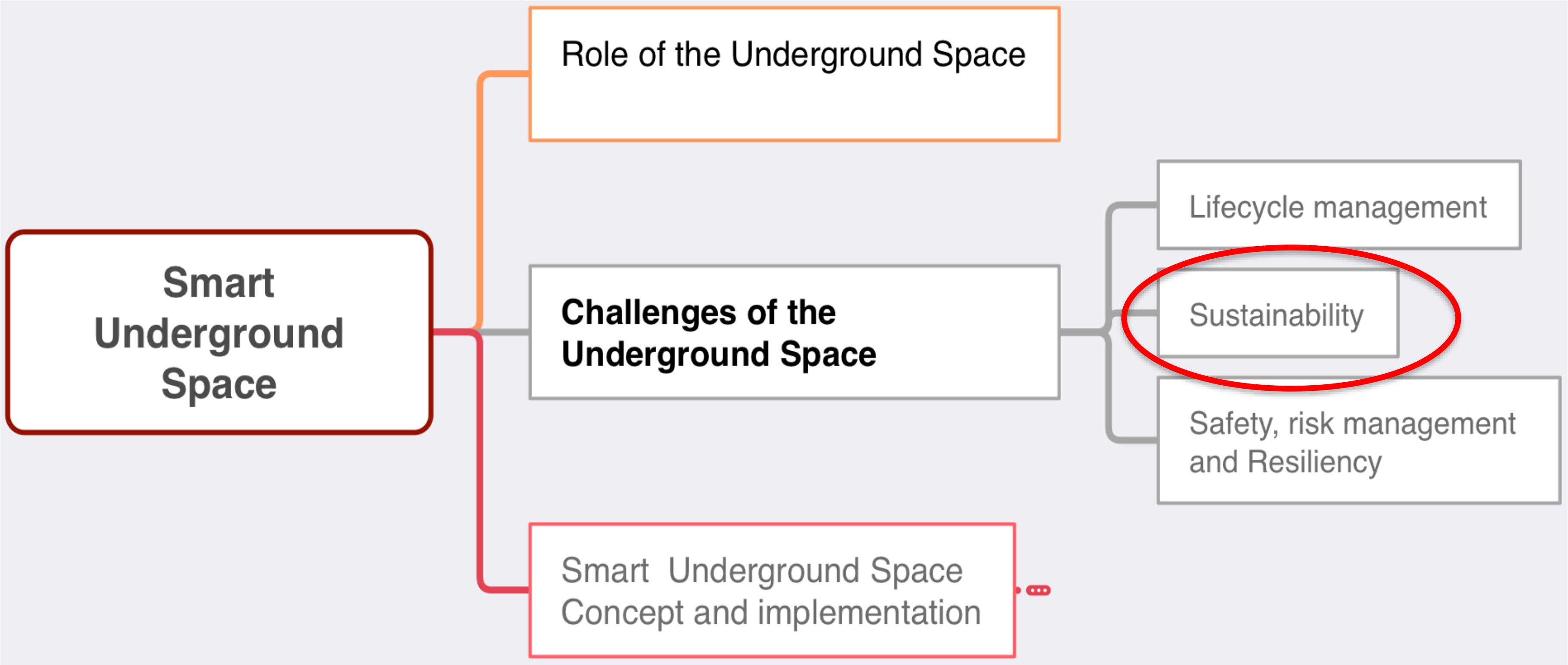
- Electrical and mechanical devices
- Air quality
- Safety - Emergency
- Inspection
- Maintenance
- Traffic, weather, events,.

Data the Lifecycle management

Questions :

- How can we conserve, manage and use data all over the lifecycle of the underground facility ?
- Which tools should we develop for data analysis and visualization ?
- How GIS and BIM technologies could help ?
- How we can combine these technologies ?

Outline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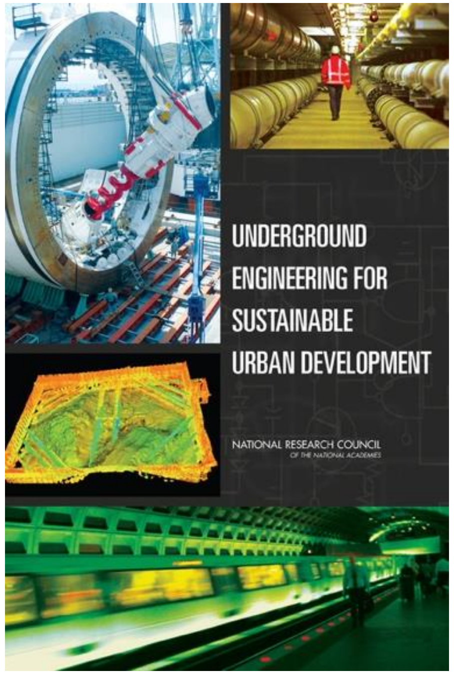
Sustainability – Environment

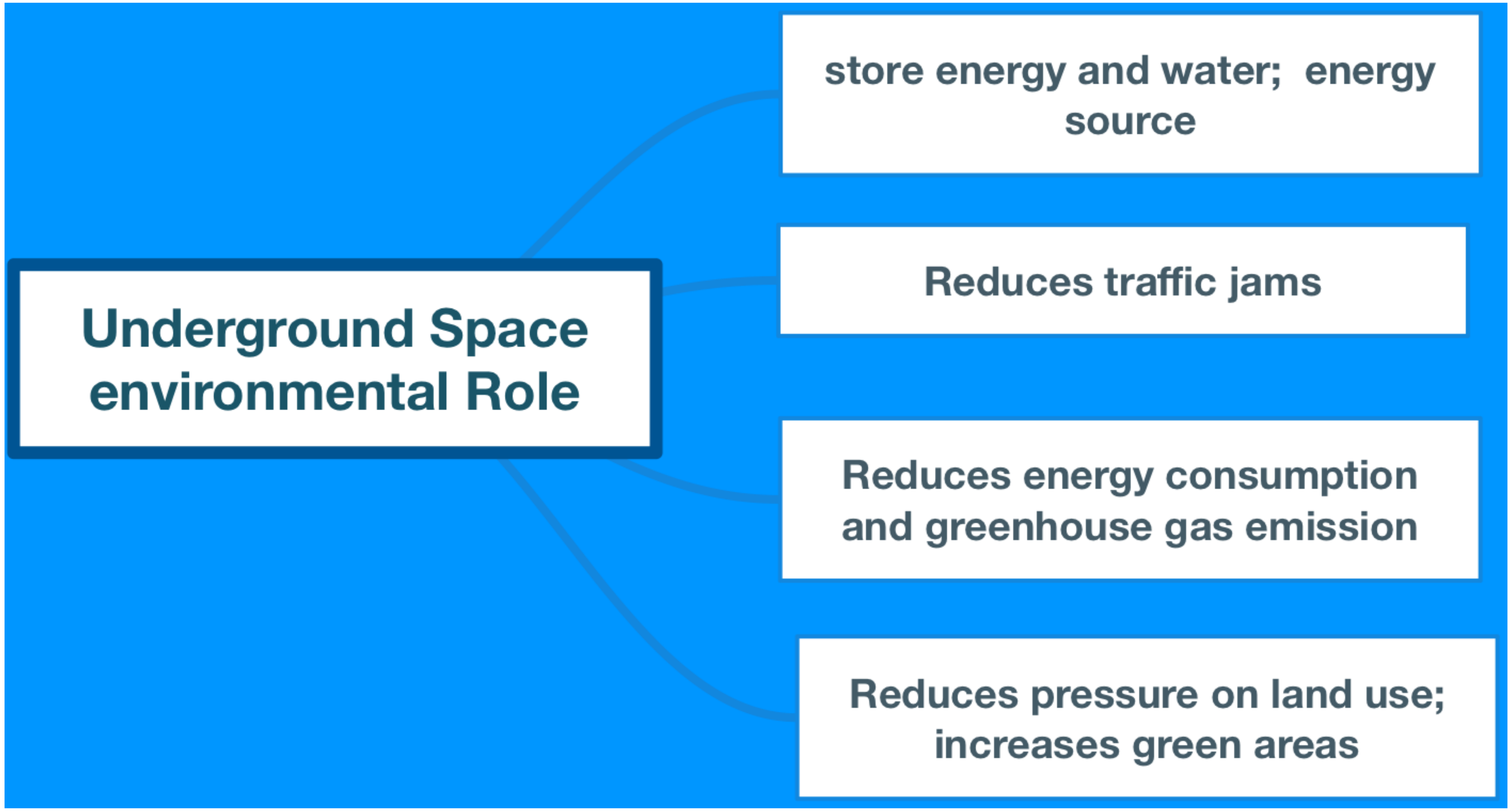
Integrated eco- friendly strategy for underground facilities ?

This role was confirmed by the report «Underground Engineering for Sustainable Urban Development » of:

- *Committee on Underground Engineering for Sustainable Development,*
- *Committee on Geological and Geotechnical Engineering,*
- *Board on Earth Sciences and Resources Division on Earth and Life Studies National Research Council*



Underground Space has a major environmental role



Sustainability – Environment

Integrated eco- friendly strategy for underground facilities ?

Planning → **Design** → **Construction** → **Exploitation**

- Eco Urban planning
- Eco Geo- environmental
- Set up indicators

2) Sustainability – Environment

Integrated eco- friendly strategy for underground facilities ?

Planning → Design → Construction → Exploitation

- Urban planning
- Geo- environmental
- Set up indicators

- Construction process (green)
- Excavated soil re-use
- Impact on the subsoil, water and biodiversity
- Energy and water consumption
- Check and complete indicators

Sustainability – Environment

Integrated eco- friendly strategy for underground facilities ?

Planning → **Design** → **Construction** → **Exploitation**

- Urban planning
- Geo- environmental
- Set up indicators

- Construction process (green)
- Excavated soil re-use
- Impact on the subsoil, water and biodiversity
- Energy and water consumption
- Check and complete indicators

- Use of green technology
- Reduction of water and energy consumption
- Prevention of soil, water and air pollution
- Treatment of excavated soil
- Reduction of disturbance to citizens
- Check and complete indicators

Sustainability – Environment

Integrated eco- friendly strategy for underground facilities ?

Preliminary studies → **Design** → **Construction** → **Exploitation**

- Urban planning
- Geo- environmental
- Indicators

- Construction process
- Excavated soil re-use
- Impact on the subsoil and water
- Energy and water consumption
- Check and complete indicators

- Use of green technology
- Reduction of water and energy consumption
- Prevention of soil, water and air pollution
- Re-use of excavated soil
- Reduction of disturbance to citizens
- Check and complete indicators

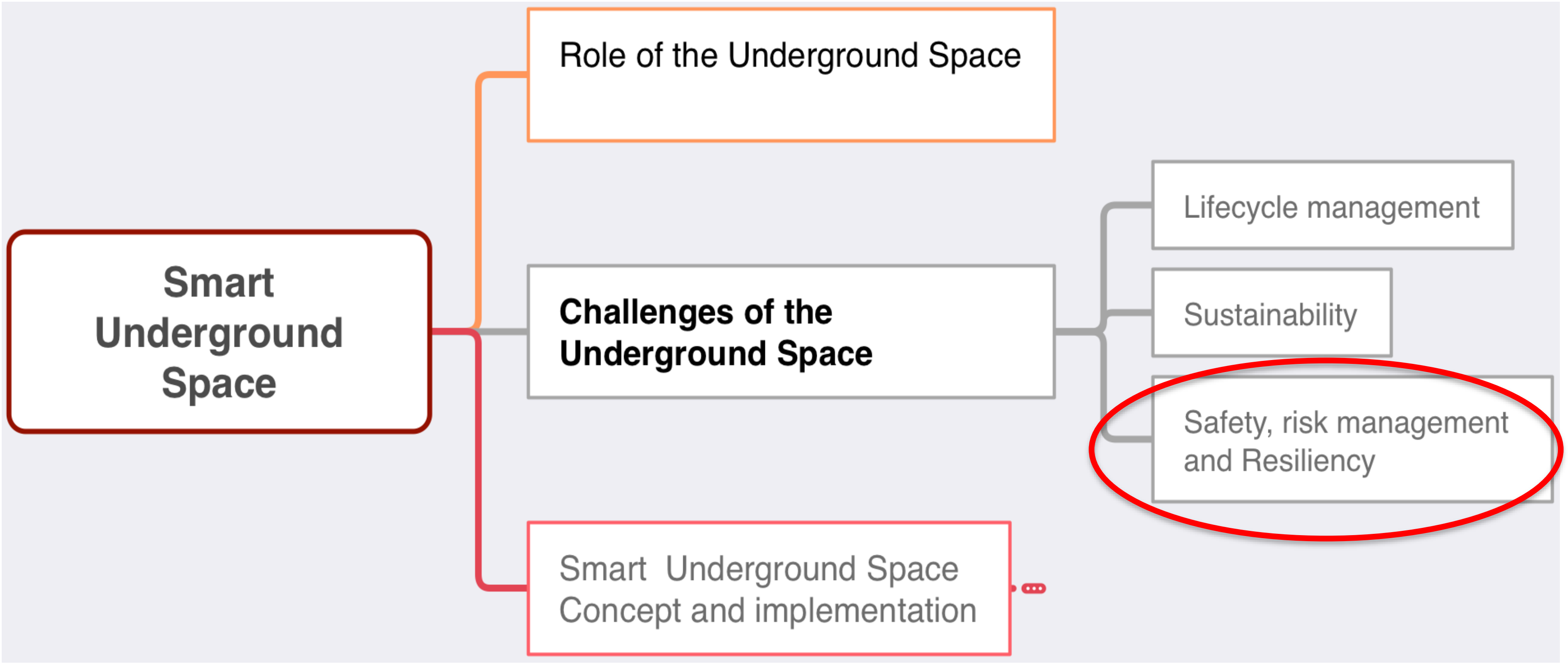
- Reduction of Energy and Water Consumption
- Air Quality
- Local energy production
- Quality of services to users
- Check and complete indicators

Sustainability – Environment

Questions :

- How to develop an integrated sustainability approach ?
- How to promote the use of this approach ?
- What are the sustainability indicators for each phase ?
- How to determine and use these indicators ?

Outline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Safety, risk management and Resiliency

Safety in the underground space is more critical than in the surface space, because of access restriction.
Accidents could occur during the construction or exploitation stages.

Accidents concern:

- Structural instability,
- water infiltration,
- Fire,
- Electrical outage,
- Air contamination
- Accidents

Safety, risk management and Resiliency

In some cases, an accident such as flood or fire could lead to serious damages to other systems of the underground space.

Integrated strategy for underground resiliency and risk management?

Preliminary studies → **Design** → **Construction** → **Exploitation**

- Identification of safety challenges (Indicators)
- Integration of safety and resilience

Safety, risk management and Resiliency

Integrated strategy for underground resiliency, safety and risk management?

Preliminary studies → **Design** → **Construction** → **Exploitation**

- Identification of the safety challenges (Indicators)
- Integration of safety and resilience

- Identification of the safety and resilience challenges (Indicators)
- Integration of the Smart Technology in the safety issue … Real-time supervision and équipement control

Safety, risk management and Resiliency

Integrated strategy for underground resiliency, safety and risk management?

Preliminary studies → **Design** → **Construction** → **Exploitation**

- Identification of the safety challenges (Indicators)
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- Monitoring of the soil-structure movement and hydraulic parameters
- Use of historical and real – time data for safety

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Safety, risk management and Resiliency

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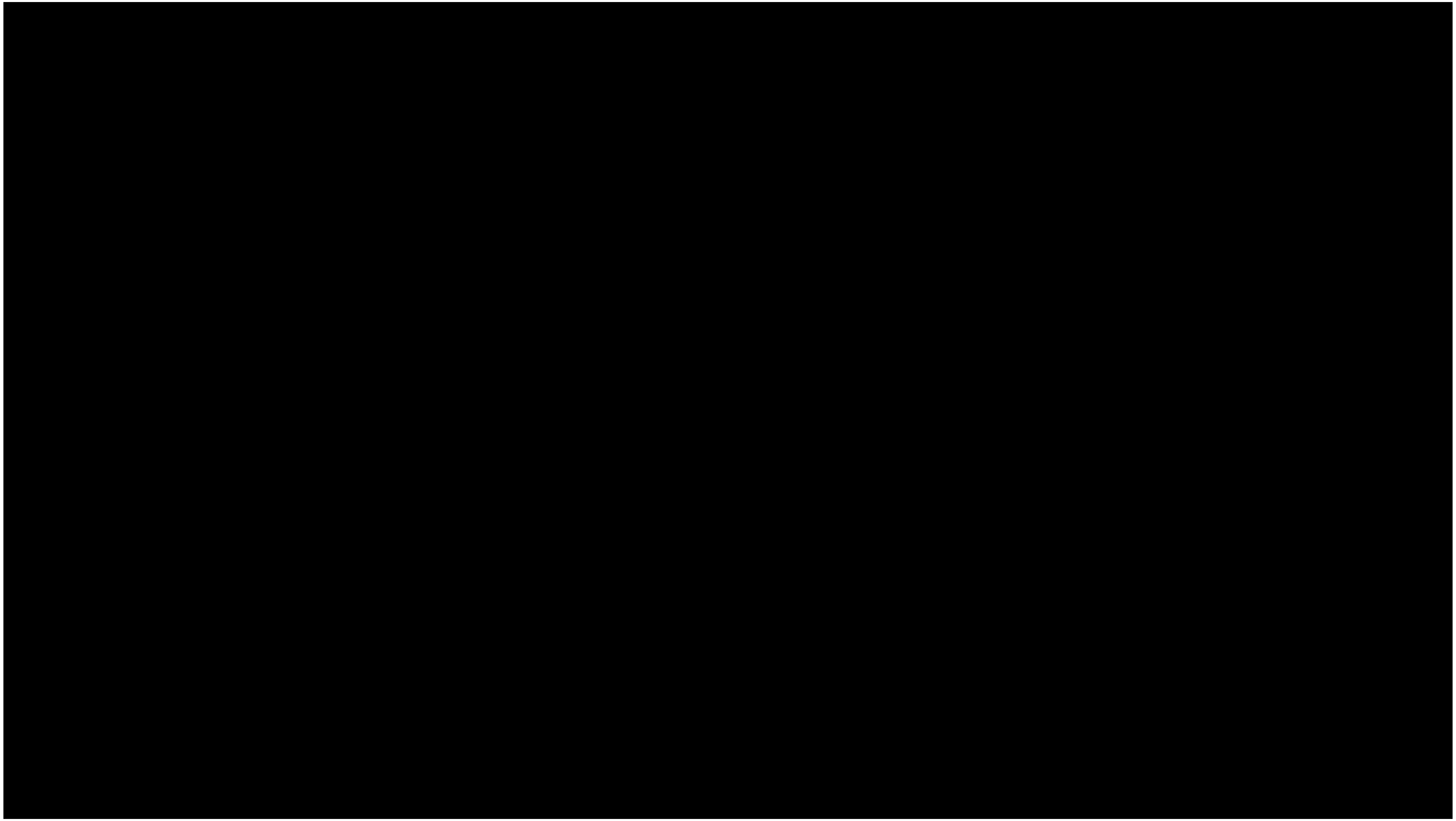
- Identification of the safety and resilience challenges (Indicators)
- Monitoring of the soil-structure movement and hydraulic parameters
- Interpretation of the excavation parameters
- Use of historical and real – time data for safety

- Identification of the safety and resilience challenges (Indicators)
- Real-time monitoring and control of the space and equipment
- Decision based on real-time and historical data

Tunnel Fire Drill

Storm floods D.C. Metro station



Safety, risk management and Resiliency

Questions :

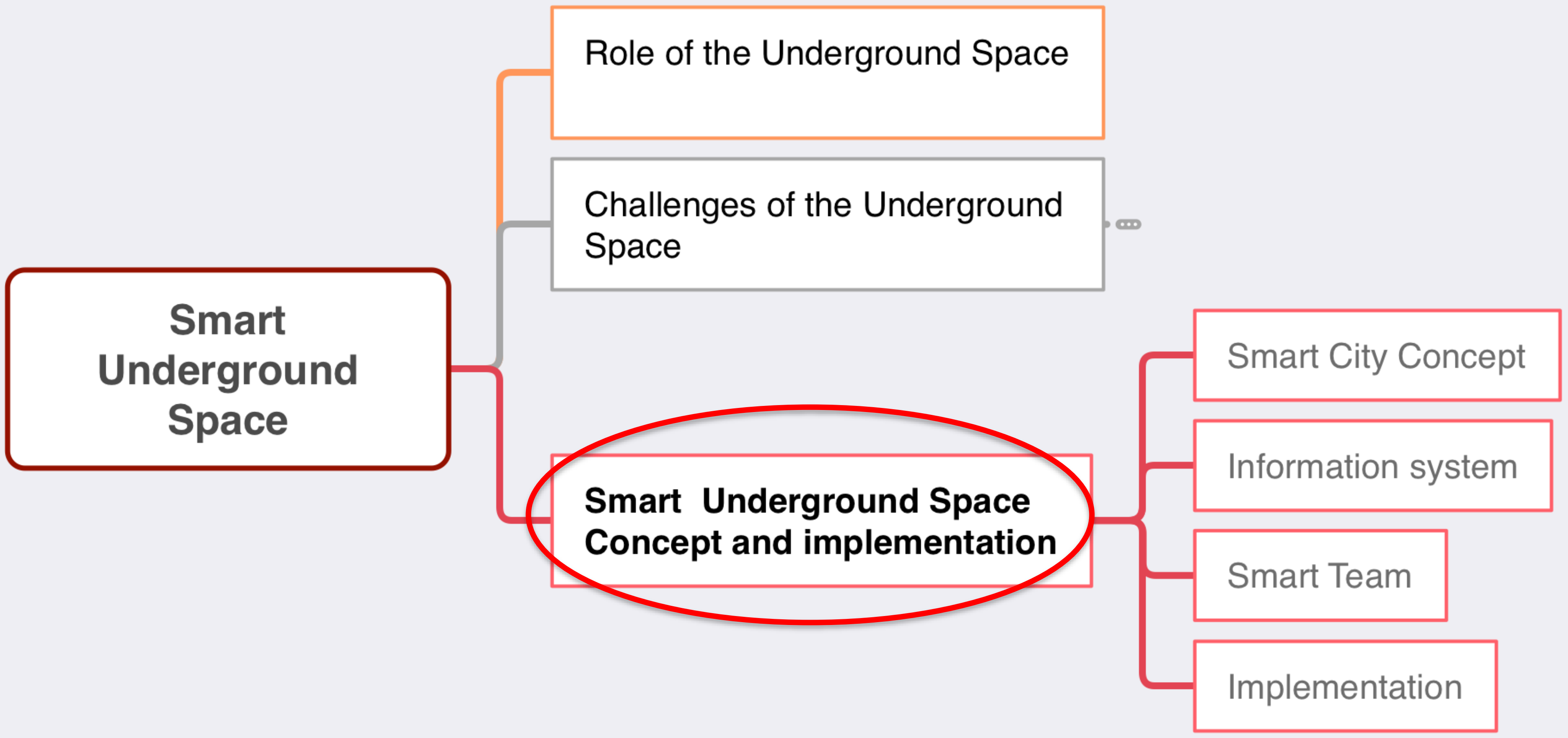
- How to develop an integrated safety and resiliency approach?
- How the Smart Technology could help in the implementation of this strategy ?
- How to implement the Smart Technology?

To meet the underground space challenges, we need innovative solutions

Smart Solution:
An inclusive system with advanced tools for data collection, storage, analysis, sharing and visualization

Analysis of **real-time and historical data** enhances the optimal and safe management of the underground space.

Outline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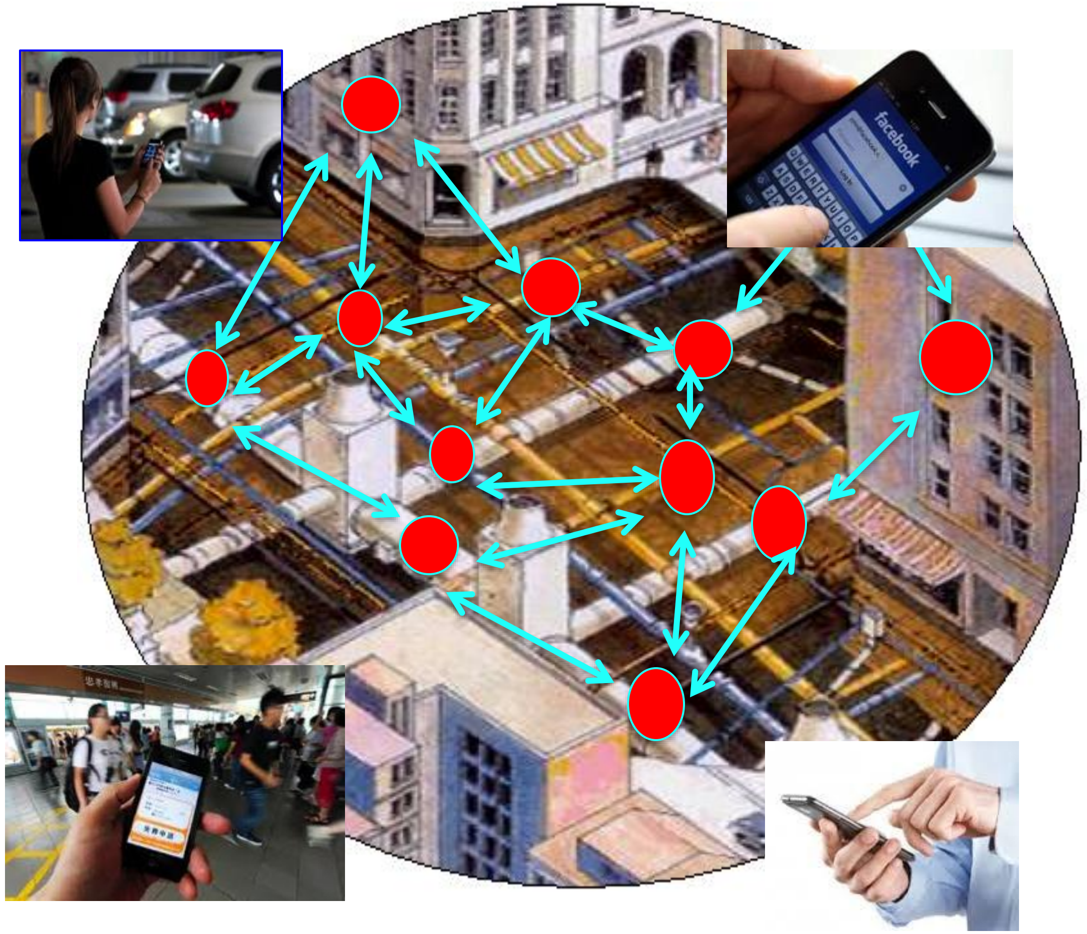
Smart City Concept
Information system
Smart Team
Implementation

Smart City



Real Time

- **See**
- **Analyze**
- **Understand**
- **Take collective decision**
- **Operate actions:**
  - Optimization
  - Security

Smart underground space layers

Physical layer

- Underground space
- Equipment
- Indoor Environment
- Users

Monitoring layer

- Sensors (IoT)
- Cameras
- Robots,
- Users

Data center & operation

- Data storage
- Data cleaning
- Data fusion
- Data analysis

Smart services

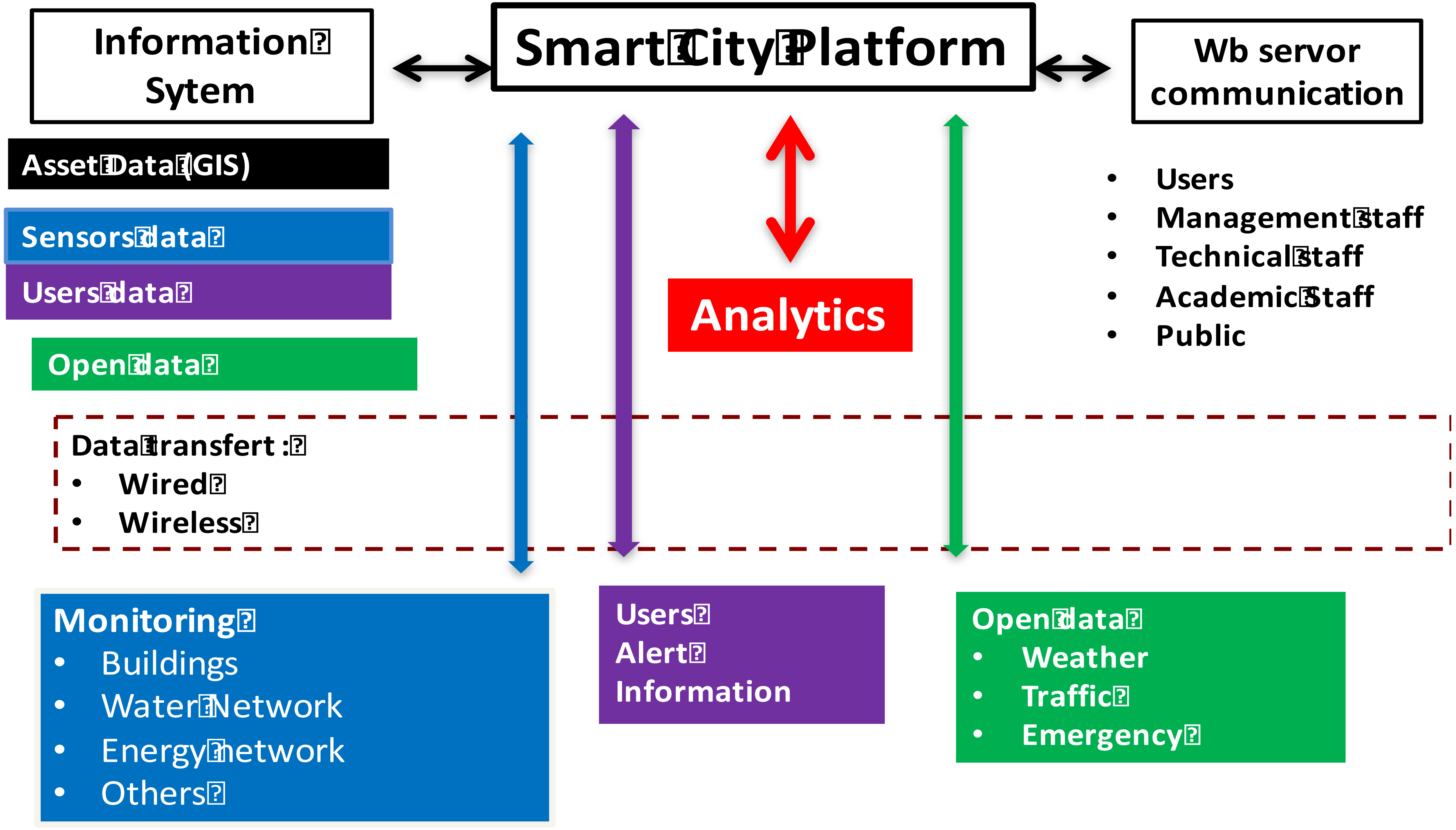
- Safety and security
- Optimal management
- Maintenance
- Services to users

Control layer

Physical layer

- Underground space
- Equipment
- Indoor Environment
- Users

Architecture of the Smart System



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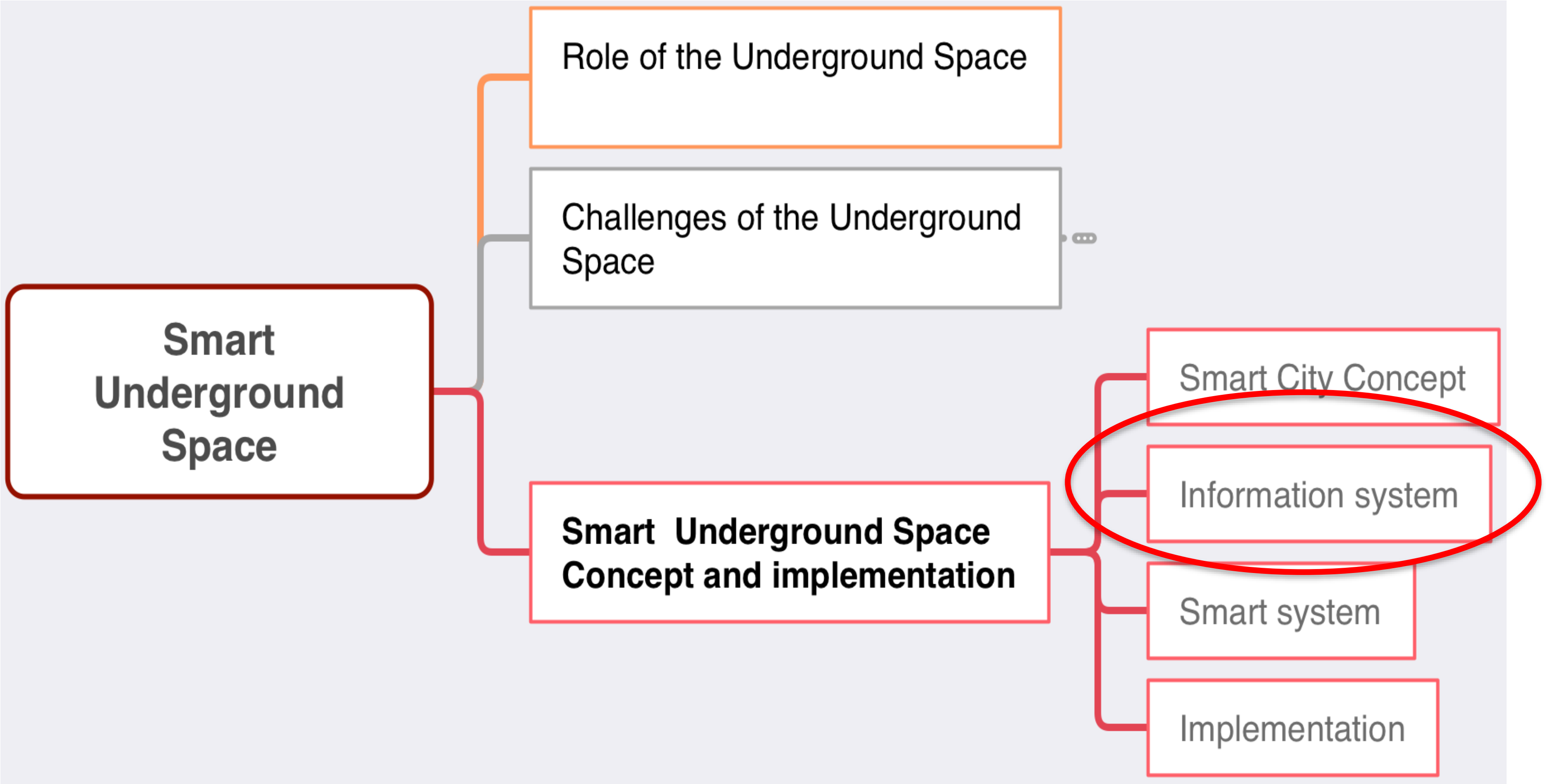

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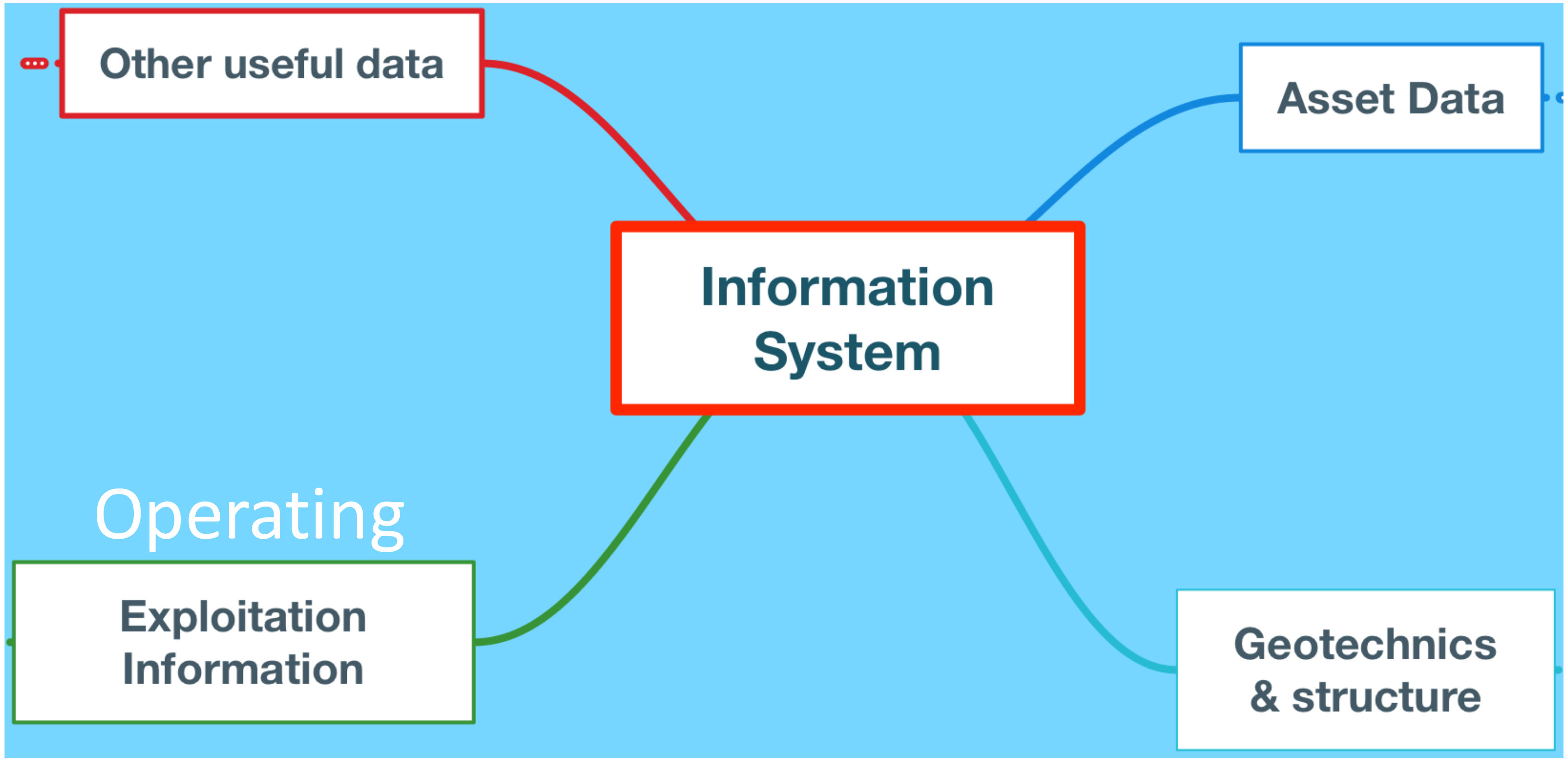
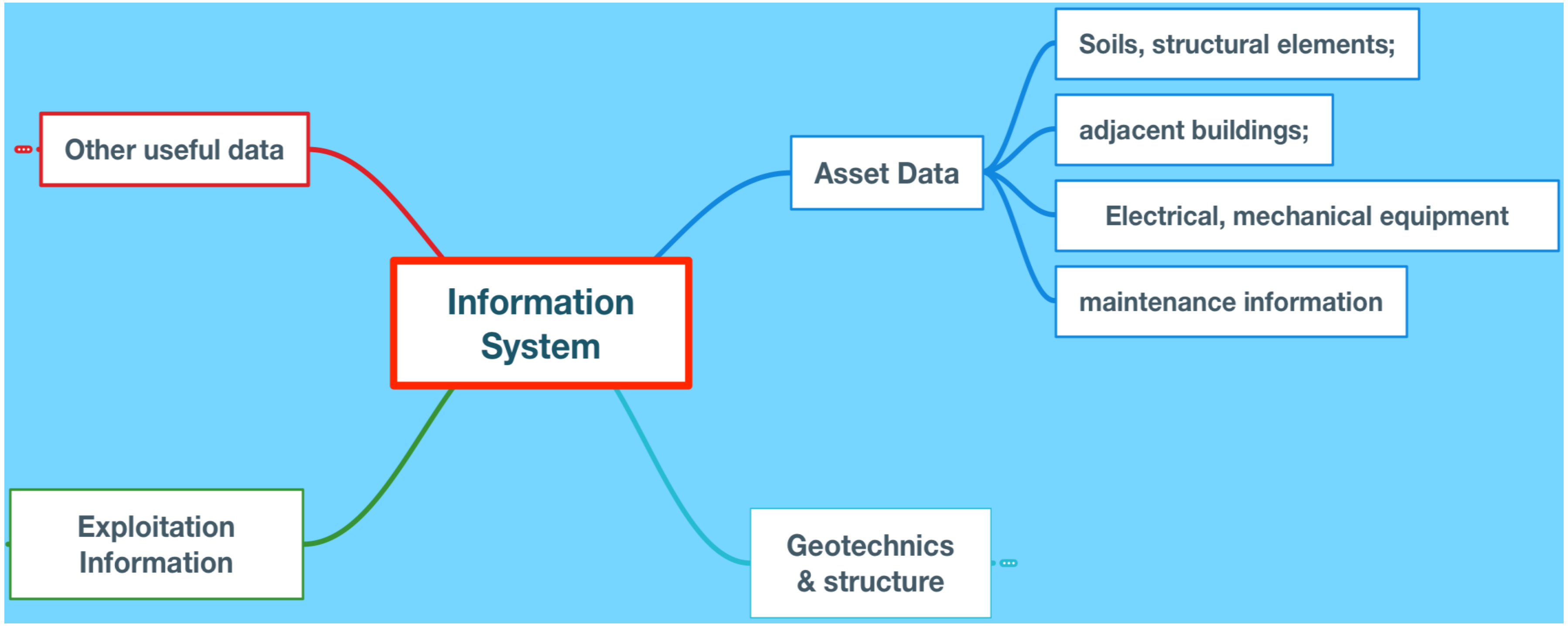

Other useful data
Asset Data
Information System
Operating
Exploitation Information
Geotechnics & structure


Other useful data
Information System
Asset Data
Soils, structural elements;
adjacent buildings;
Electrical, mechanical equipment
maintenance information
Exploitation Information
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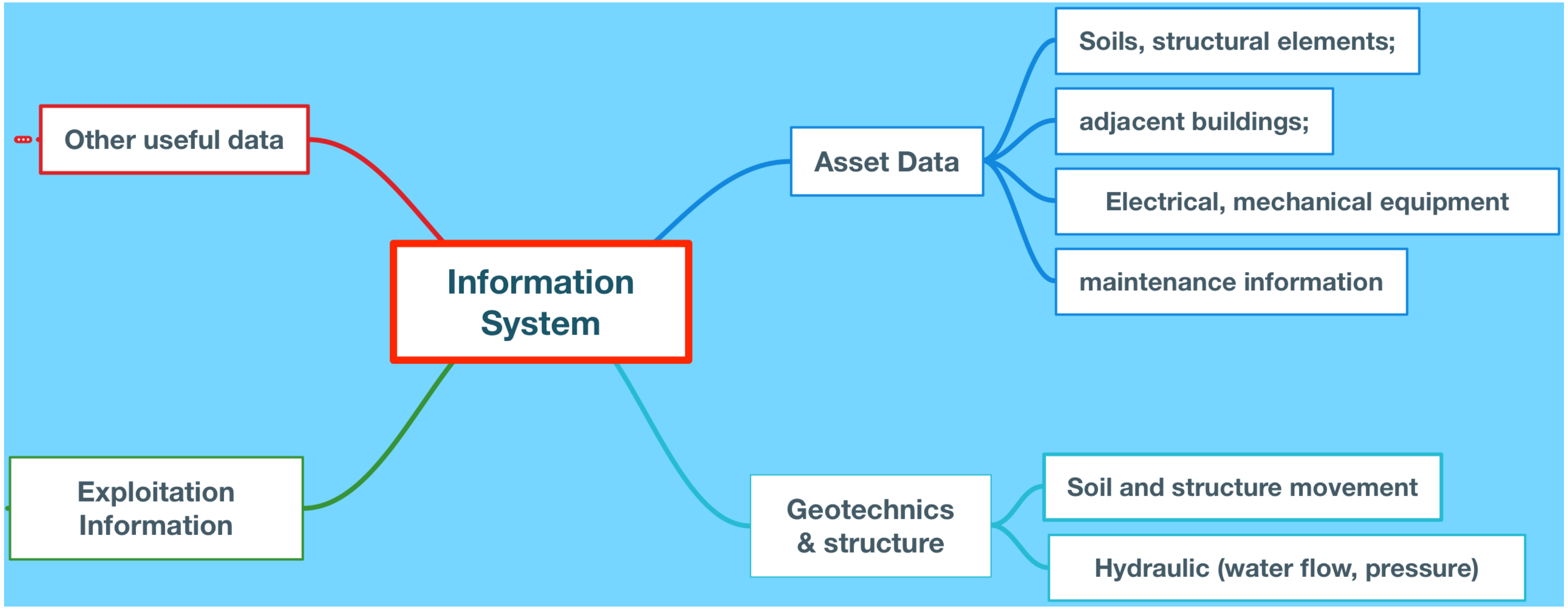
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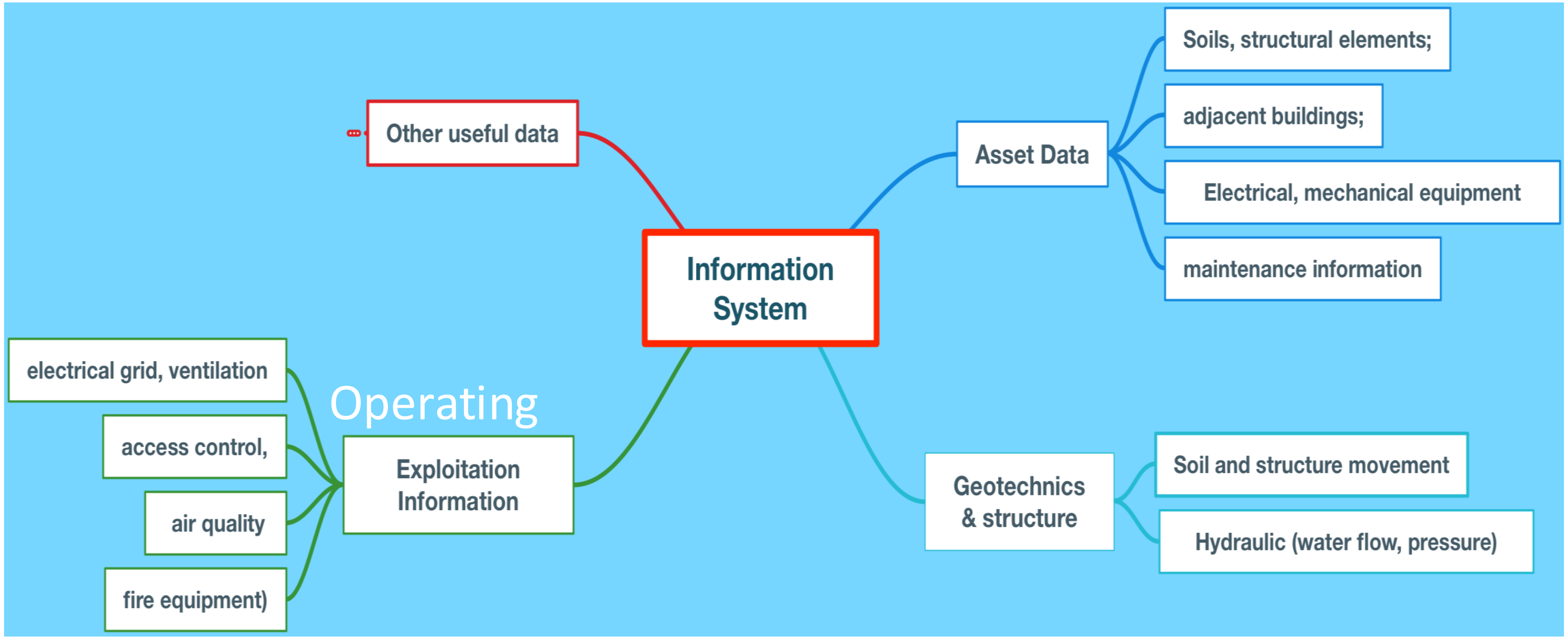
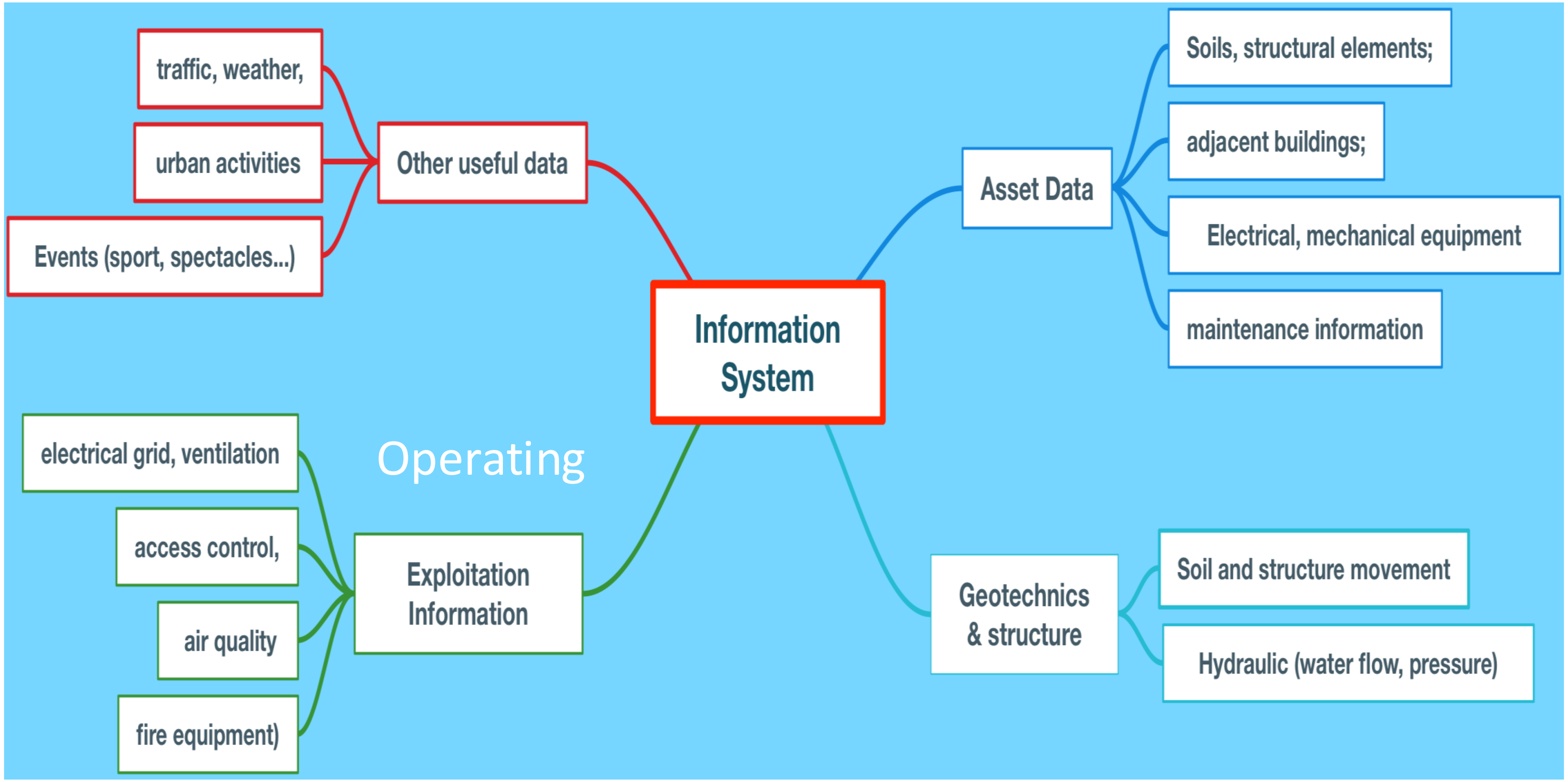
Soil and structure movement
Hydraulic (water flow, pressure)


Other useful data
Asset Data
Soils, structural elements;
adjacent buildings;
Electrical, mechanical equipment
maintenance information
Information System
electrical grid, ventilation
Operating
access control,
Exploitation Information
air quality
fire equipment)
Geotechnics & structure
Soil and structure movement
Hydraulic (water flow, pressure)


traffic, weather,
urban activities
Events (sport, spectacles...)
Other useful data
Information System
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Soils, structural elements;
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maintenance information
Operating
electrical grid, ventilation
access control,
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fire equipment)
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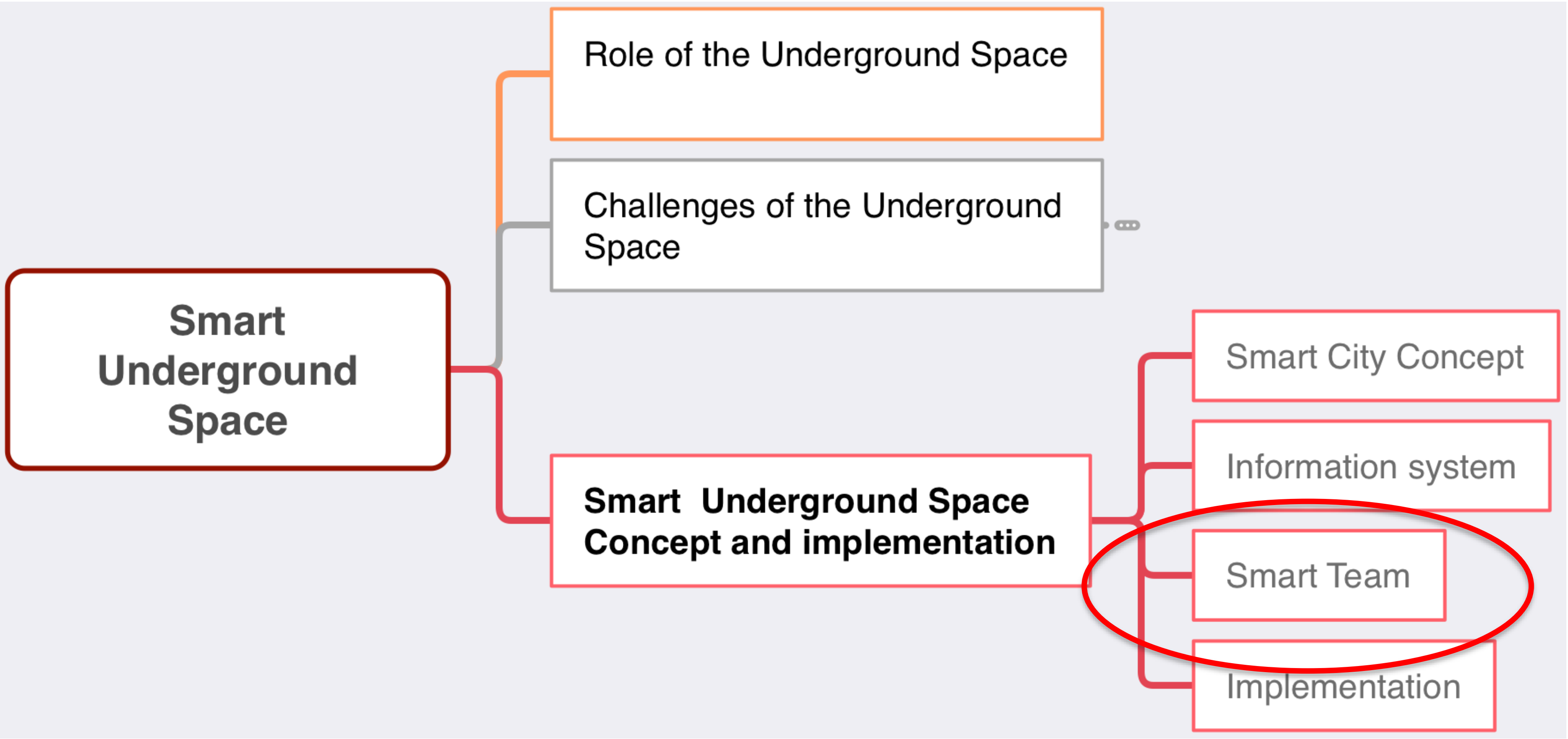
Hydraulic (water flow, pressure)

Data management

Data management could use professional tools such as:

- Geographic Information System (GIS)
- Building Information Modelling (BIM).
- Civil Information Modelling (CIM)

Outline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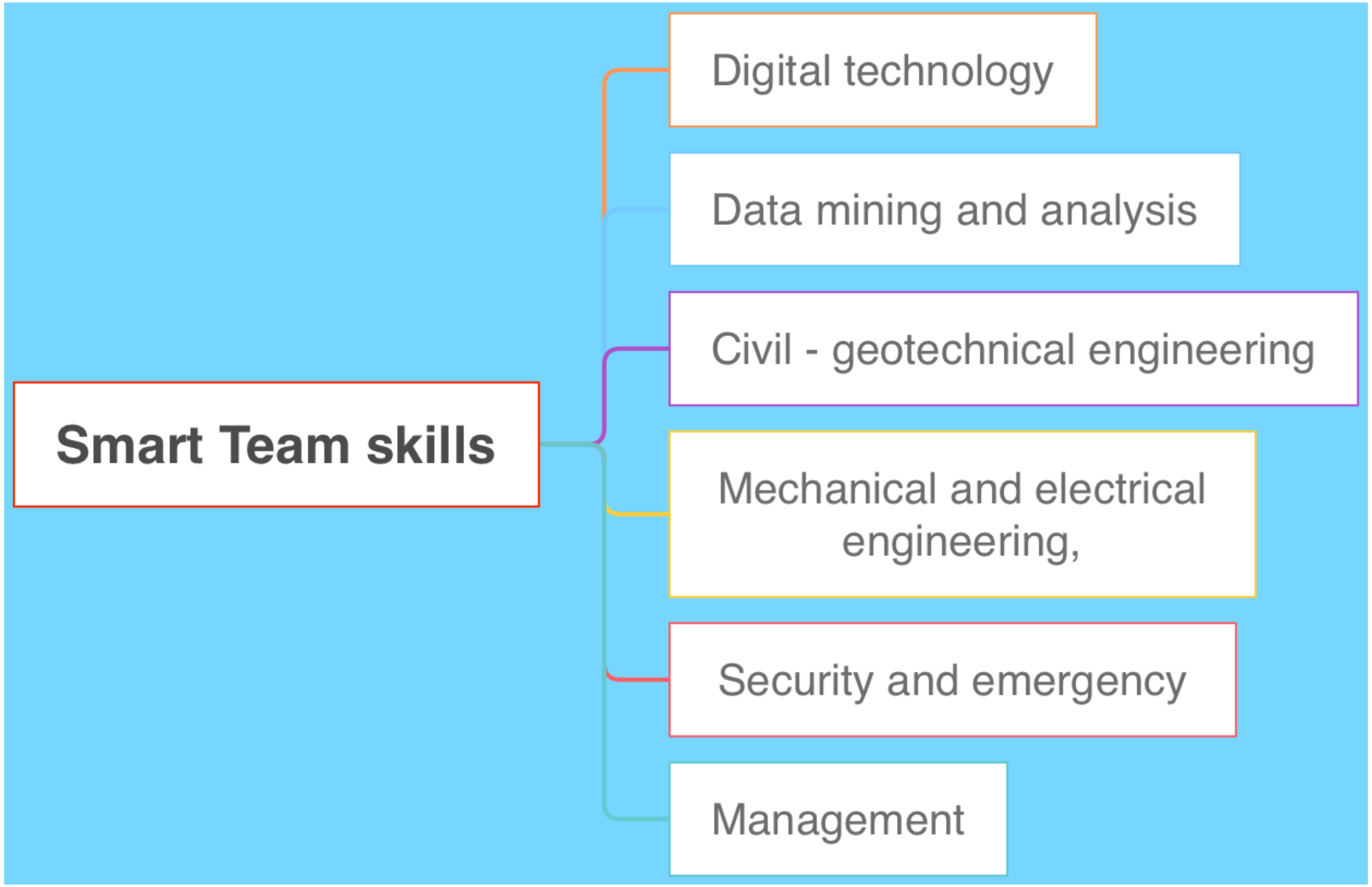
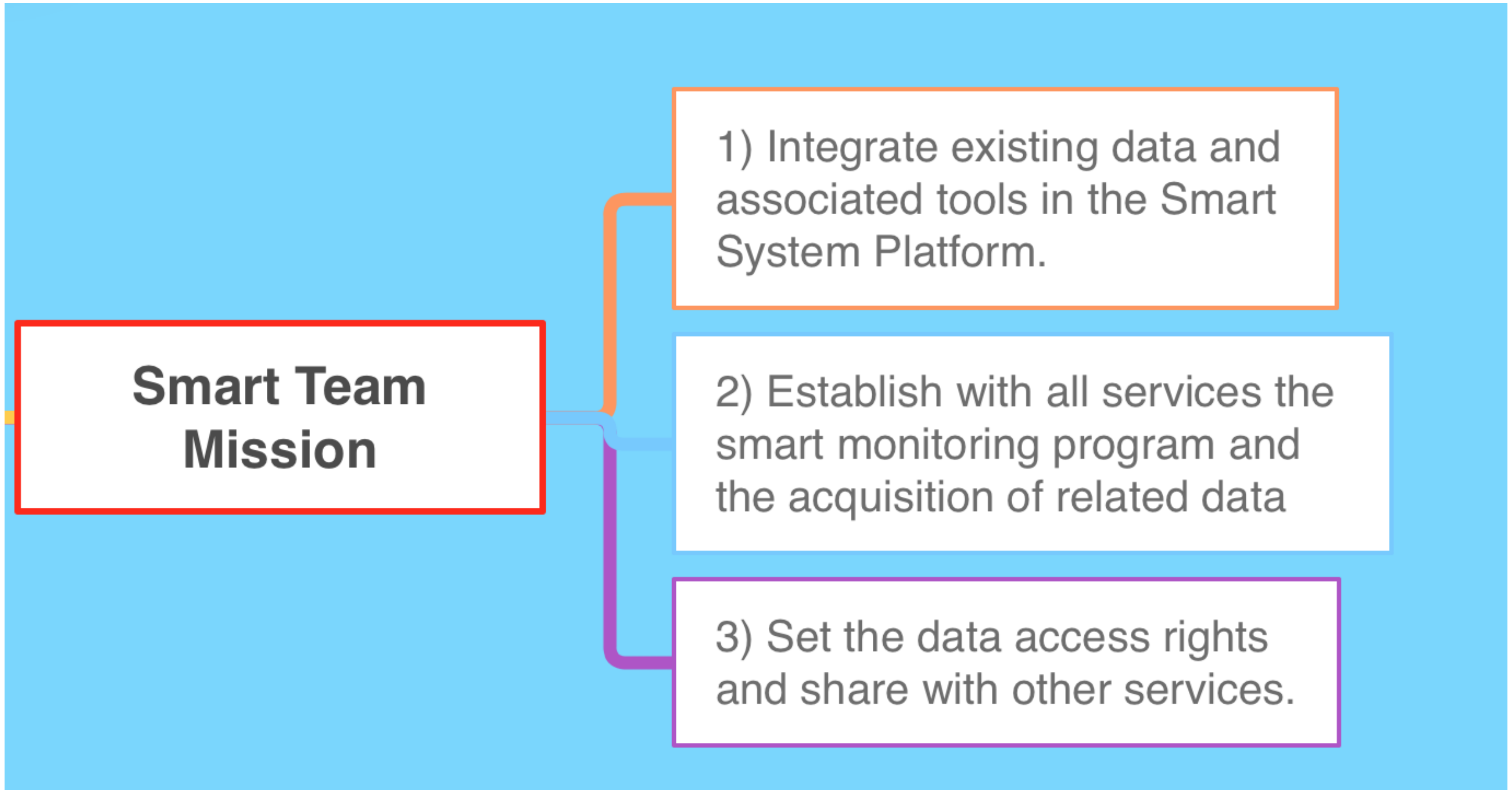
Smart Team

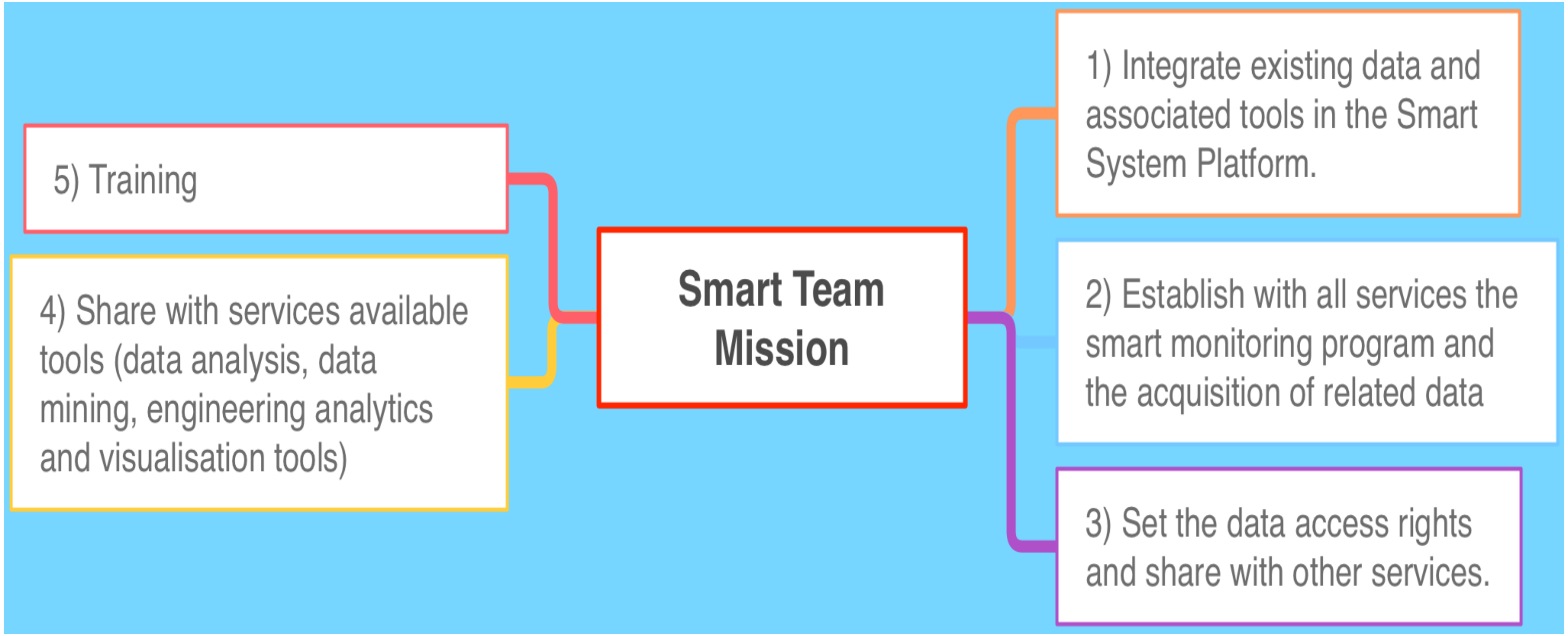
Designation of a smart team with multidisciplinary skills



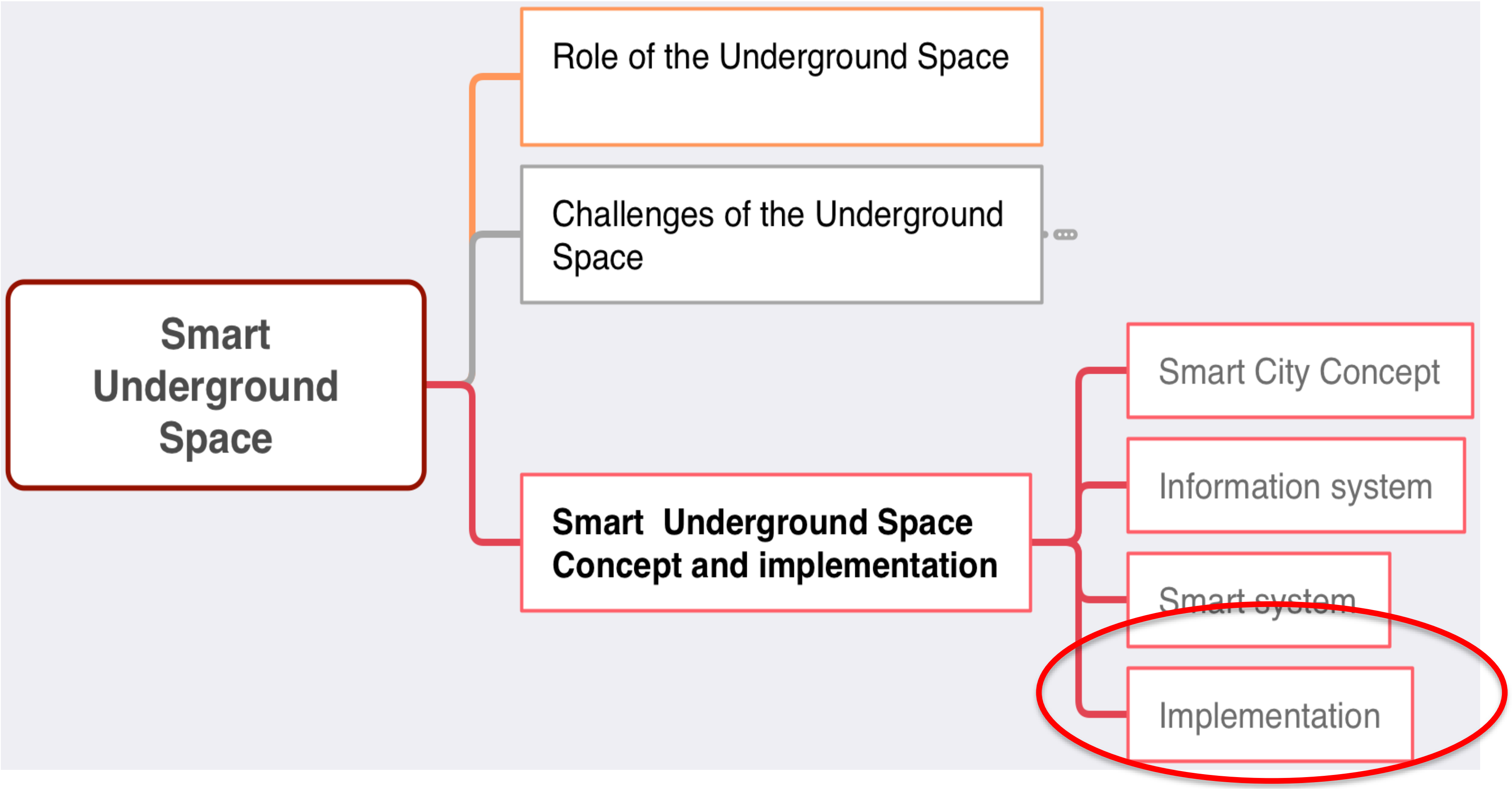
Smart Team Mission



Smart team



5) Training
4) Share with services available tools (data analysis, data mining, engineering analytics and visualisation tools)
Smart Team Mission
1) Integrate existing data and associated tools in the Smart System Platform.
2) Establish with all services the smart monitoring program and the acquisition of related data
3) Set the data access rights and share with other services.



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Smart System for underground space

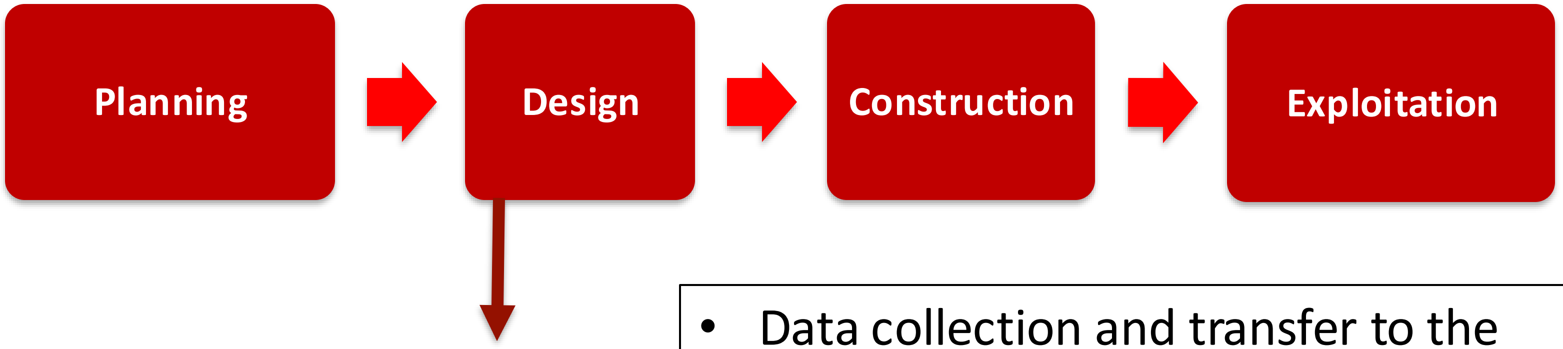
Work to conduct at each step

Planning → Design → Construction → Exploitation

- Identification of parameters to be followed and controlled
- Design of the monitoring system
- Design of the Information System
- Design of the control system
- Construction of the Smart Platform (GIS, BIM, CIM,…)

Smart System for underground space

Work to conduct at each step



- Identification of parameters to be followed and controlled
- Design of the monitoring system
- Design of the Information System
- Design of the control system
- Construction of the Smart Platform

- Data collection and transfer to the Information system
- Use of Data for the control of the excavation process and environment
- Performance analysis

Smart System for underground space

Work to conduct at each step

Planning → Design → Construction → Exploitation

- Identification of parameters to be followed and controlled
- Design of the monitoring system
- Design of the Information System
- Design of the control system

- Construction of the Smart Platform (GIS, BIM, CIM,…)

- Data collection and transfer to the Information system
- Use of Data for the control of the excavation process and environment
- Performance analysis
- Share of data & information

- Data collection and transfer to the IS
- Use of Data for the control of the equipment, devices, environment
- Performance analysis
- Share of data & information
- Users information

Conclusion

The underground space has a major economic, social and environmental role

Lifecycle management and safety require advanced monitoring and control systems for the soil, structural elements, mechanical, electrical and security equipment.

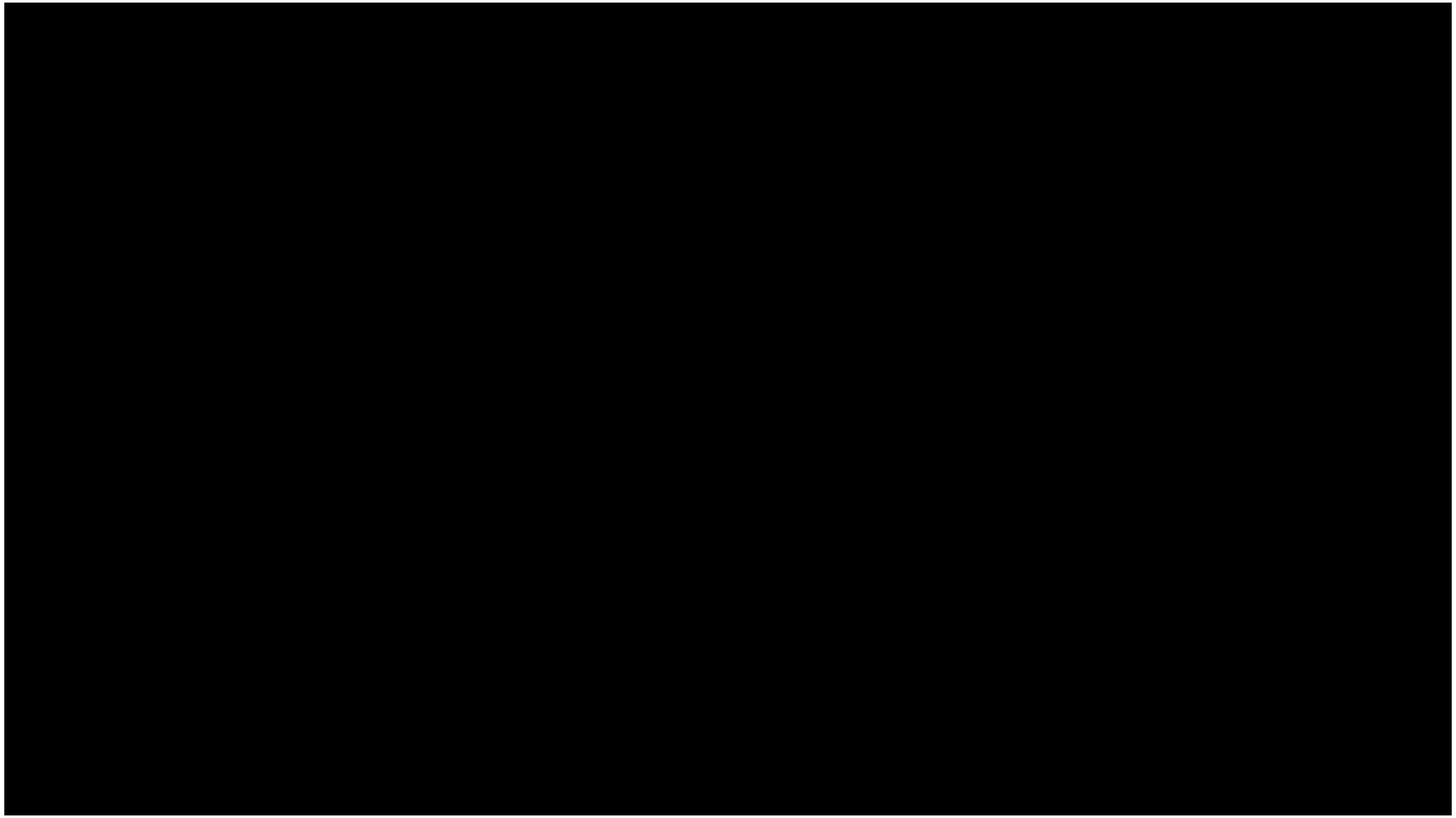
Smart City concept allows development of a comprehensive system that uses digital technology and data throughout the underground space life for an optimal and safe management of this space.

Smart System for the safety

According to the type of incident, the system should:

- Ensure data and information transmission to services and authorities concerned by the incident.
- Take appropriate actions through a control of devices and equipment to confine the incident and ensure emergency measurements.
- Use data collected to enhance the underground space resiliency.

Transforming the London Underground Internet of Things



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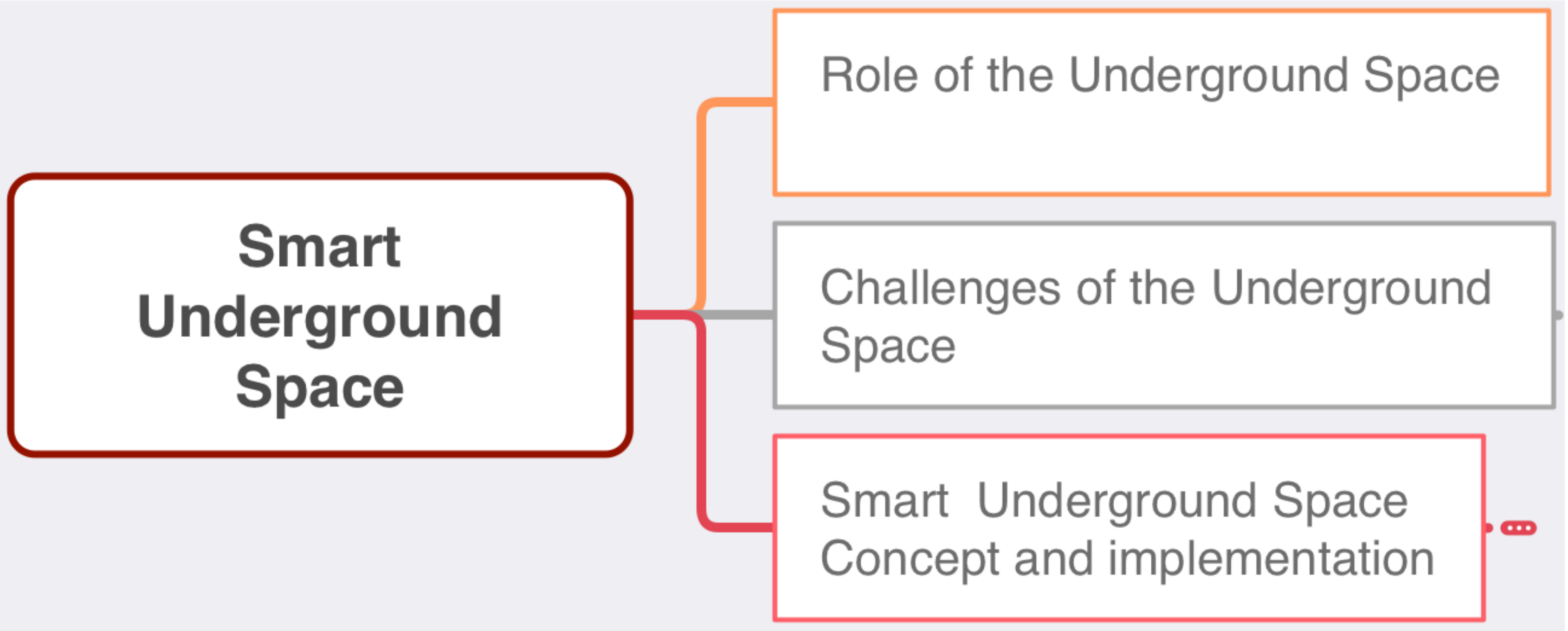
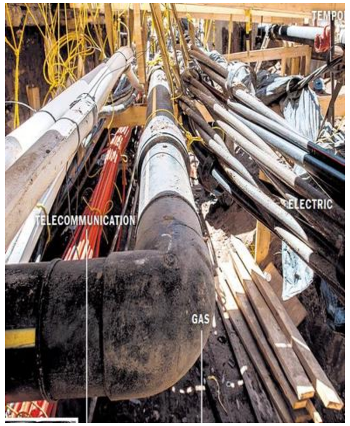
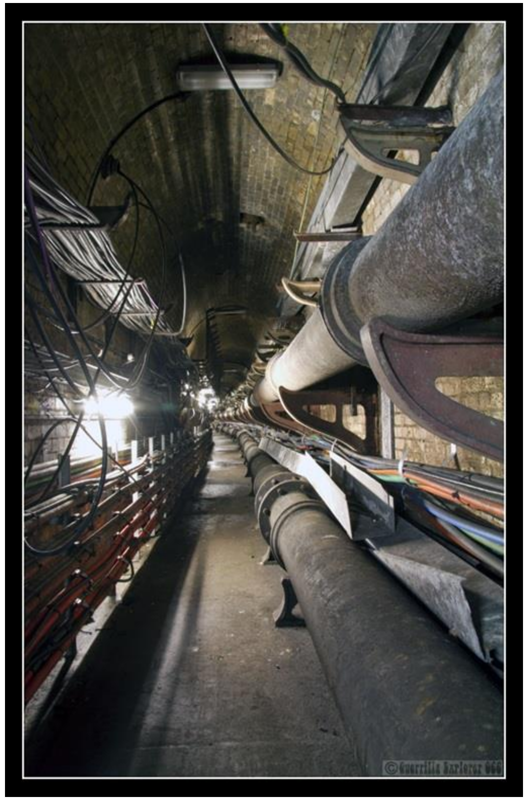


Part 2 Smart utility tunnel

Utility tunnel is an excellent solution

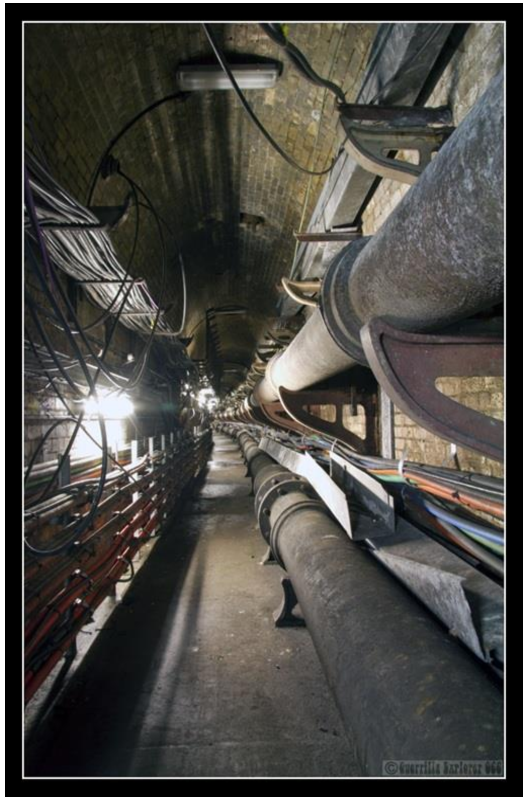




Utility tunnel
(safety box)

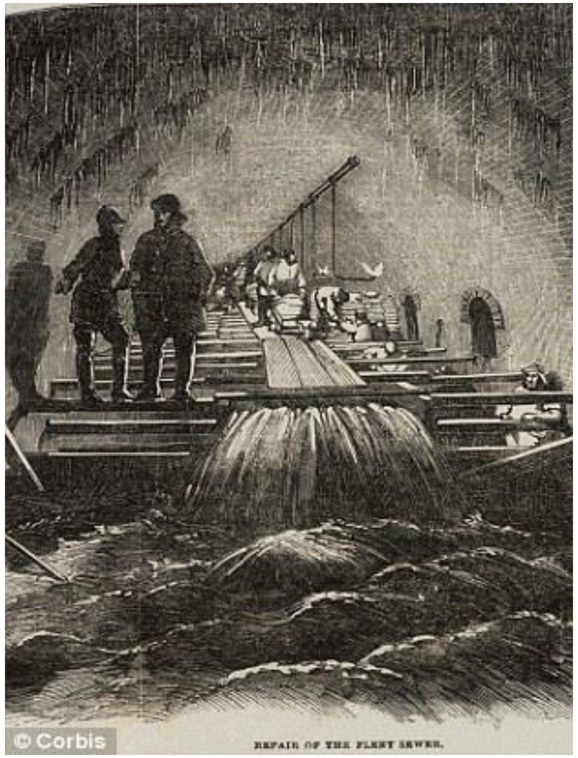
Any system containing one or more utilities, which is "visitable" without excavation

Utility tunnel is an excellent solution



- Avoids trenches and traffic disturbance
- Reduces risk of utilities damage during works.
- Facilitates installation, inspection, replacement and preventive and predictive maintenance.
- Protects from environmental and working aggressions.
- Facilitates management of construction wastes.
- Saves fill materials

London in the 19^{th} Century



1845

1854

Construction and reparation of London sewage system

http://www.dailymail.co.uk/news/article-2038281/London-underground-photos-Miles-ornate-brickwork-tunnels-hidden-Fleet-River.html

Amsterdam

Construction 2002 - 2005
New Business District

- Water supply
- Sanitation
- Storm water
- Gas
- District heating
- Cold network
- Electricity
- Telecommunications

District Heating
Electrical

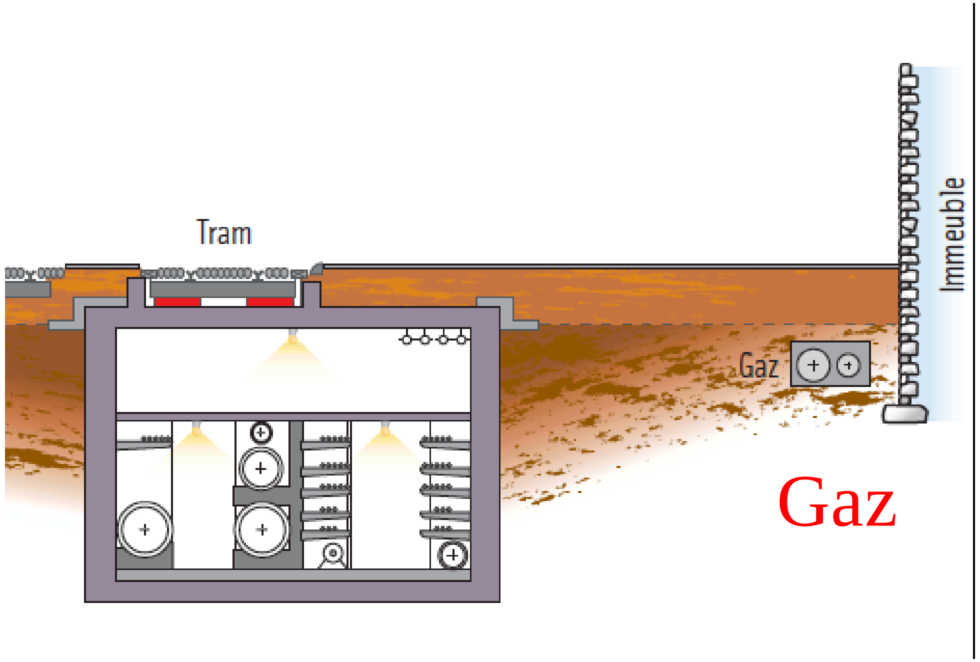
Others

CléSol

Geneva

Construction 1985 -1989

- Electricity
- water,
- Telephone,
- Roads light control
- sewage
- storm water



~~Gaz~~

CléSol

Utility Tunnels in China

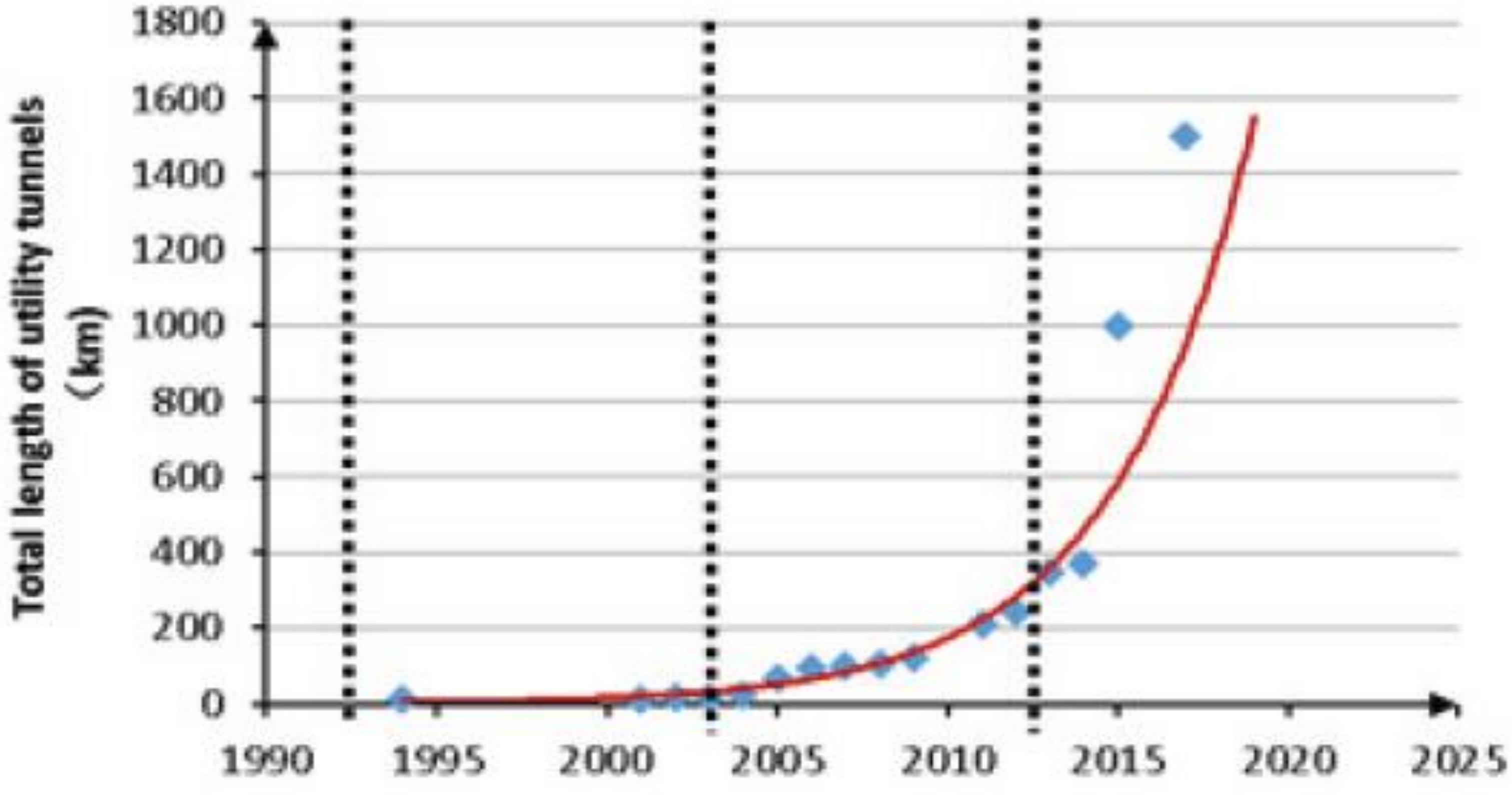


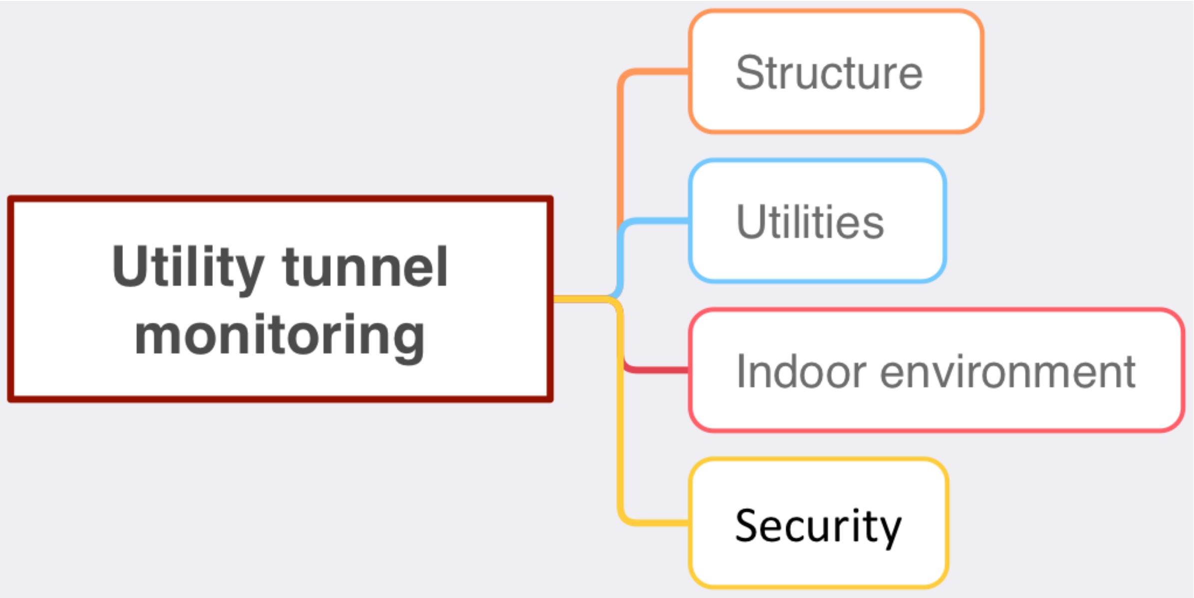
Fig. 3. Growth curve of utility tunnels built in China.

Chao Yang and Fang-Le Peng / Procedia Engineering 165 (2016) 540 – 548

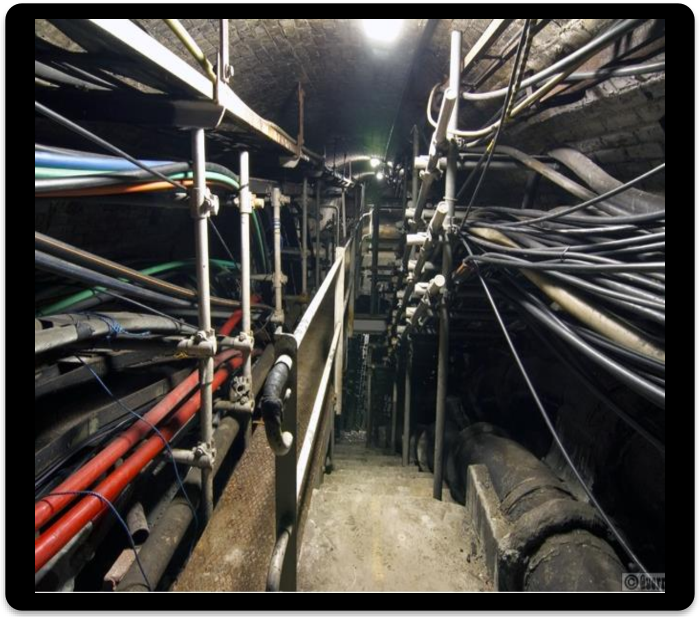
Challenges of utility tunnels

- Critical infrastructures for the city
- Compatibility among utilities in the tunnel environment;
- Multitude of users (Who does what ?)
- Hazards of gas leaks and explosions;
- Water pipe leaks and rupture;

Utility tunnel monitoring



Utility tunnel monitoring



1) Structure monitoring

- Deformation
- Displacement
- Water content
- Global inspection by camera

Utility tunnel monitoring

2) Utilities monitoring

Drinking water: Flow, pressure, quality
Sewage : Flow, height, quality
Electrical : current, voltage, frequency,..
Heating : temperature, flow, pressure
Gas : pressure, flow

Utility tunnel monitoring

3) Indoor monitoring

- Temperature
- Humidity
- Lighting
- Acoustic
- Air quality (gas,…)
- Air flow

Utility tunnel monitoring

4) Security monitoring

- Access (open/close)
- Occupancy
- Air quality
- Fire detection
- Ventilation system
- Smoke extractors
- Firefighting system
- Camera – video

Ball State University utility tunnels

New paper about the Smart Utility Tunnel

applied sciences

MDPI

Article

Use of Smart Technology to Improve Management of Utility Tunnels

Isam Shahrour [1,2,*], Hanbing Bian [2], Xiongyao Xie [1] and Zixin Zhang [1]

1 School of Civil Engineering, Tongji University, Shanghai 200092, China; xiexiongyao@tongji.edu.cn (X.X.); zxzhang@tongji.edu.cn (Z.Z.)

2 Laboratoire de Génie Civil et géo-Environnement, Université de Lille, 59000 Lille, France; hanbing.bian@univ-lille.fr

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check for updates

Thank You for your attention

Happy to answer your questions