The Technique Selection of Sewer Trenchless Rehabilitation in Metropolis of South China

A case study in Guangzhou city

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Contents

Background --- sewers in Guangzhou city

- Guangzhou City has a long history in modern times and is a typical metropolis of South China. The sewer in Guangzhou City center area are over 1300 kilometers.

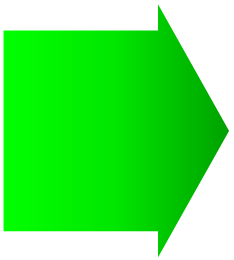
Used for over 30 years

Different pipe quality and Construction level

Overweight road load

Settling of ground

Corrosion of pipeline *etc*.



Main damages:

Cracks

Joint displacement

Open joints

Collapse etc.

Background --- sewer pipes in Guangzhou

- The damaged sewer pipes account for 73.92% of investigated total length, and mostly range from 300 to 600 mm of diameter.
- Located in the area with: dense population, active commerce and heavy traffic.

Affecting surroundings

Construction difficulty

Long construction period

High cost

Background --- trenchless rehabilitation

- Trenchless rehabilitation is an environmental technique for damaged sewer pipes, with no excavation or less excavation.
- The commonly-used at home and abroad are:
  cured-in-place pipe, slip lining, fold and form sliplining, spiral wound lining, pipe bursting, diameter reduction slipping and splice segment lining *etc*.
- In Guangzhou city, the main techniques are:

Cured-in-place pipe:

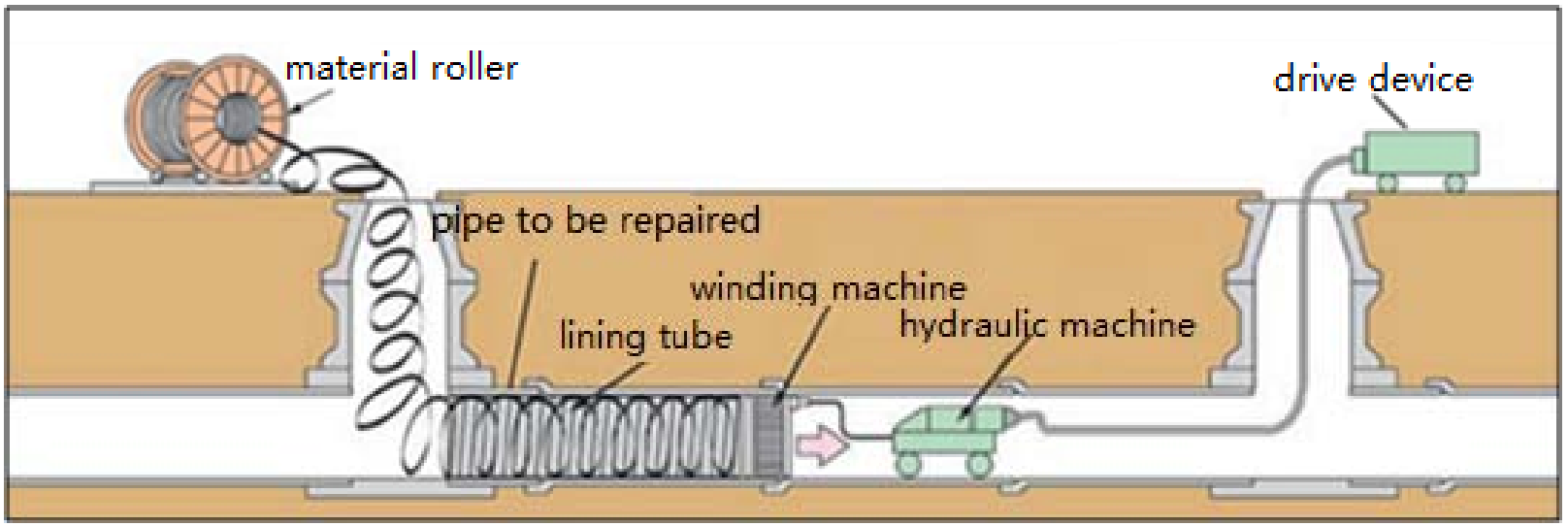
a. Pull-in lining

b. Inversion lining

c. SAERTEX-LINER UV curing

Background --- trenchless rehabilitation

Spiral wound lining:



Slip lining:

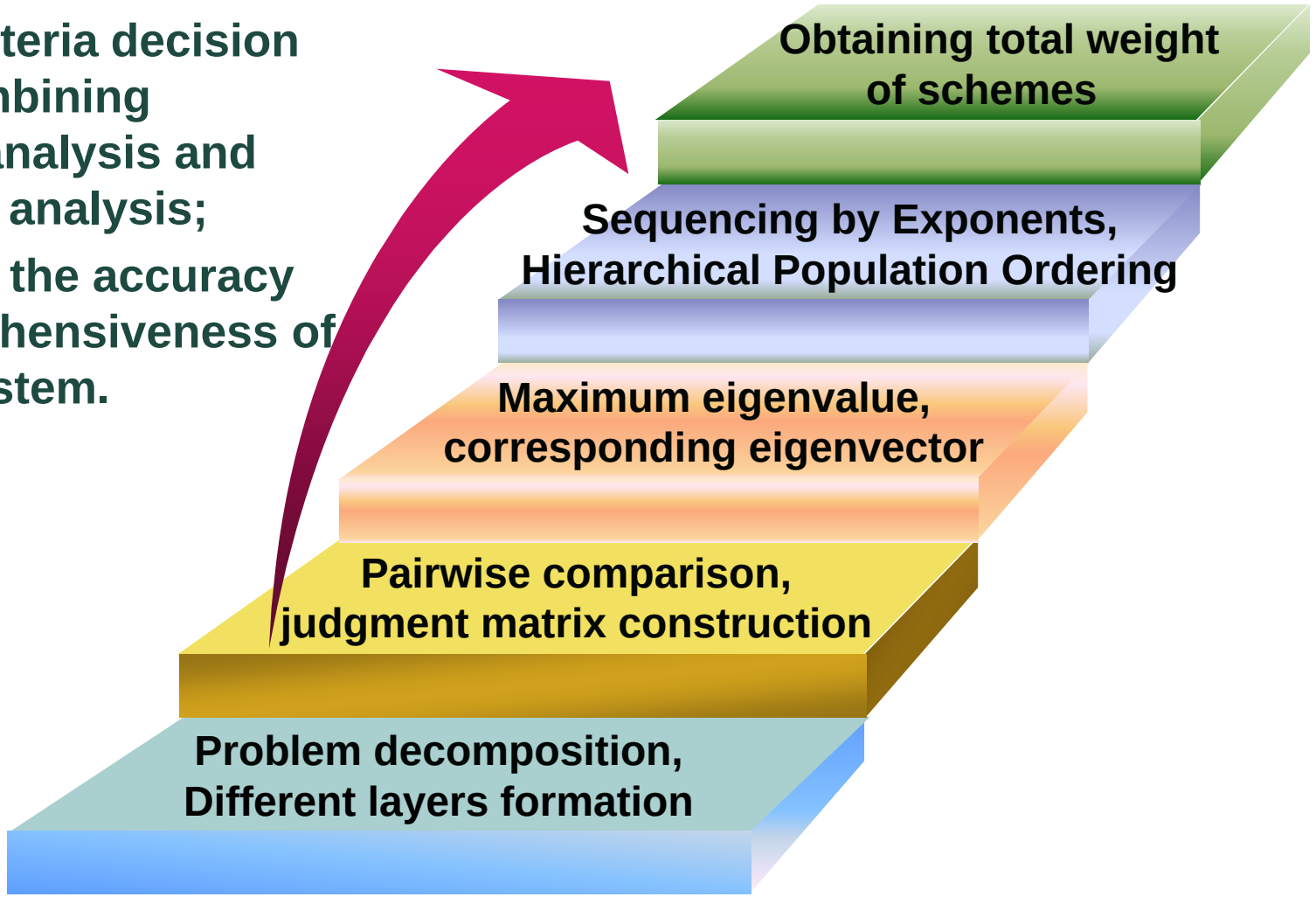
Dragging a new pipe into the old pipe directly and then inject grout into the annular space between the new and old pipes for stabilizing.

Methodology

Analytic Hierarchy Process (AHP)

Best available technique

- A multi-criteria decision method combining qualitative analysis and quantitative analysis;
- Improving the accuracy and comprehensiveness of complex system.

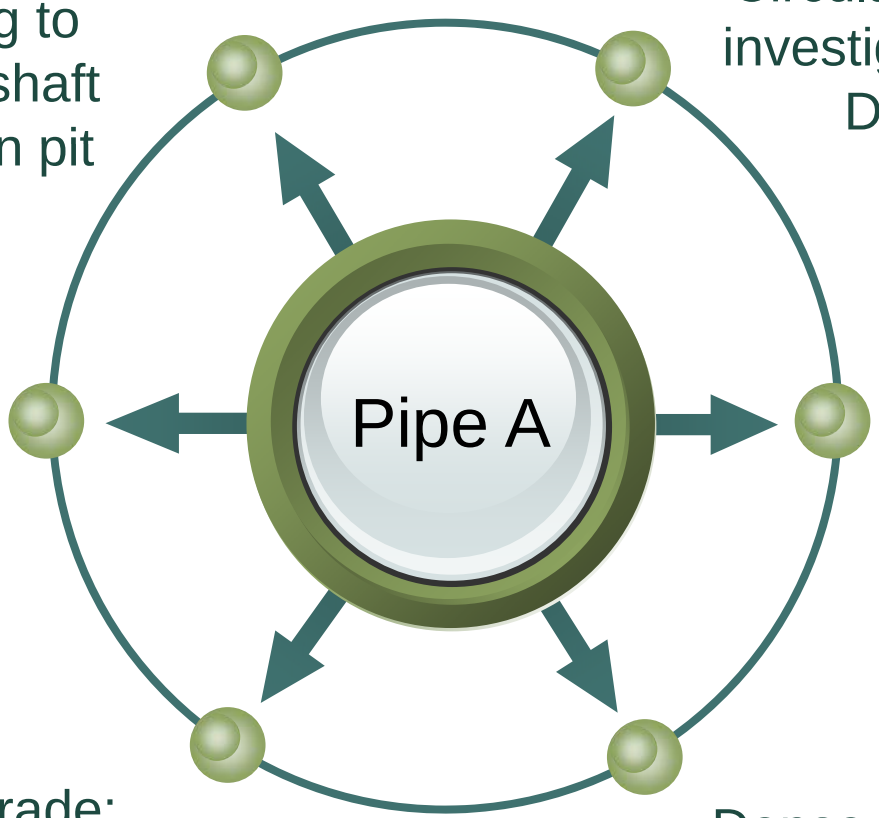


Case analysis by AHP

- **Typical Sewer to be Repaired: pipe A**

Trenchless or only allowing to set starting shaft and reception pit

Circular (96.54% of investigated pipes.), D400 mm



Concrete pipe (82.66% of all pipes)

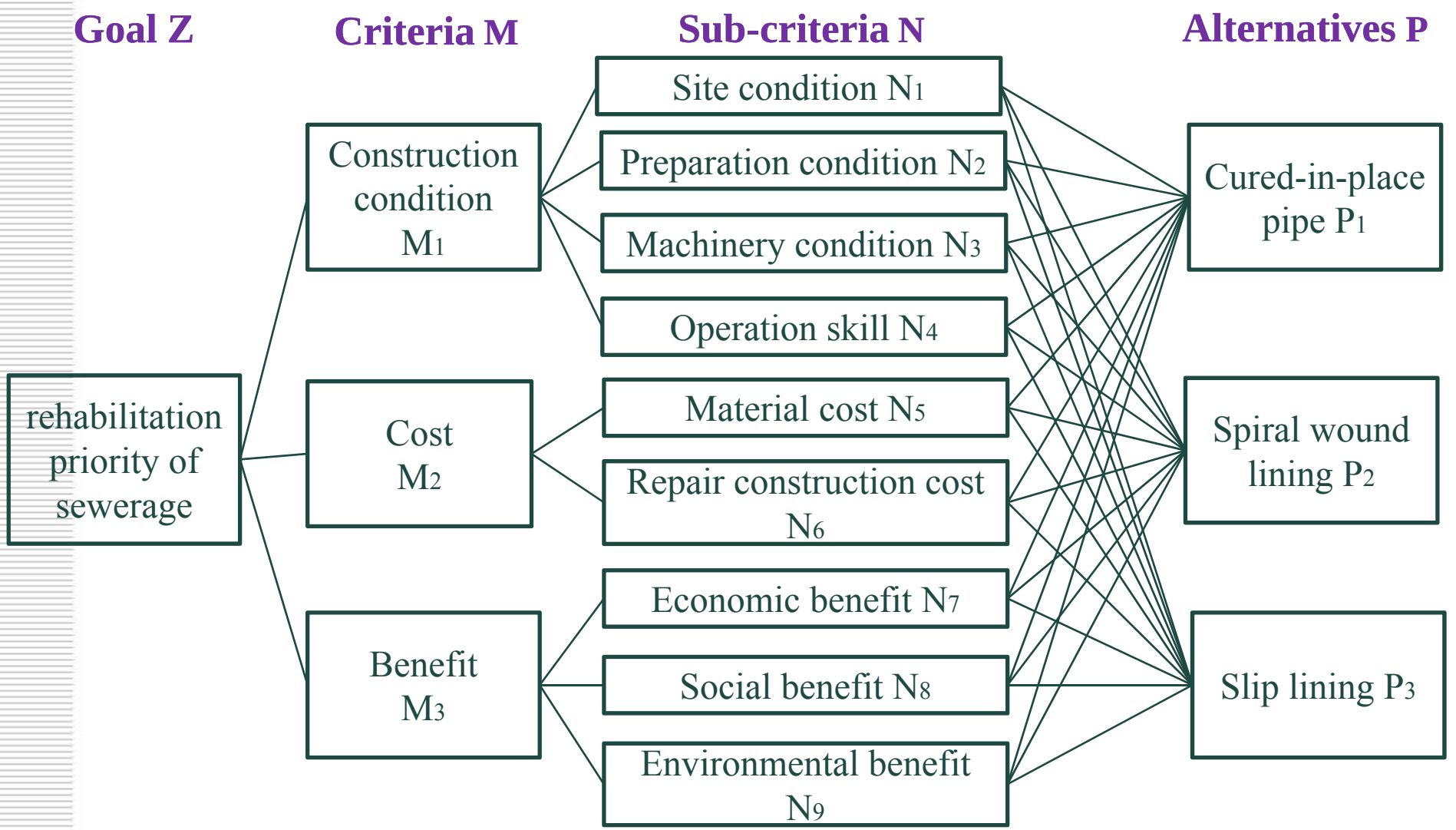
Cross-section: allowable decrease within 15% or increase to 450mm

Road Grade: Traffic artery and heavy transportation

Site Restrict: Dense population, hospitals, difficult division facility installation

Case analysis by AHP

- **AHP model of pipe A:**



Case analysis by AHP

- **Pairwise comparison**:
  by using 1-9 scaling with well perception, high precision and good rank preservation.
- **Judgment matrix construction**:
  taking Z-M layer of pipe A as an example:

Based on Z	M_1	M_2	M_3	Weight	CR Value
M_1	1	3	2	0.5396	0.0079
M_2	1/3	1	1/2	0.1634	
M_3	1/2	2	1	0.2970	

The higher the weight, the more important the M_i to Z.

Case analysis by AHP

- **Sequencing by Exponents,** i.e. the computation of weight:

$$A=\begin{bmatrix}1 & 3 & 2\\ 1/3 & 1 & 1/2\\ 1/2 & 2 & 1\end{bmatrix} \Rightarrow |\lambda E-A|=0 \Rightarrow \lambda_{max} \text{ and } W=(W_1,W_2,W_3)^T$$

After normalization of W: $$w_i=\frac{W_i}{\sum_{j=1}^{n} W_j}$$

The new vector, $w = (w_1, w_2, w_3)^T$, is the weight vector.

- **Consistency check,** i.e. the computation of CR value :

$$CI=\frac{\lambda_{max}-n}{n-1} \qquad CR=\frac{CI}{RI}$$

CI: consistency index

RI: random consistency index

CR: consistency ratio, the consistency check is passed when CR < 0.1

The same way for computing judgment matrixes of M-N layer and N-P layer.

Case analysis by AHP

- **Hierarchical population ordering**:
  showing the importance degree of every factor to the overall target.

The hierarchical population ordering value of B_i can be obtained by:

$$b_i = \sum_{j=1}^{m} a_i b_{ij} \text{(m represents the number of factors in A layer.)}$$

a_j: the hierarchical population ordering value of A_j in A layer

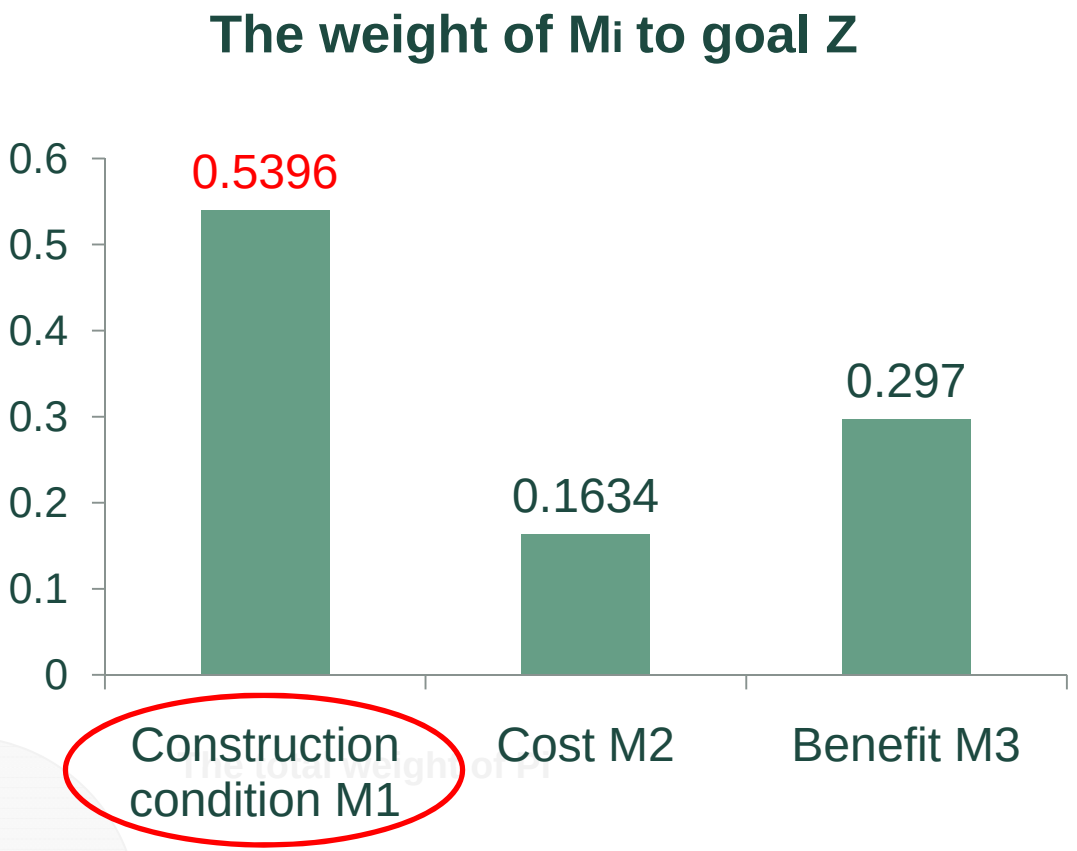
b_{ij}: sequencing by exponent of B_i in B layer to A_j

The consistency check is also needed:

$$CR = \frac{a_1 CI_1 + a_2 CI_2 + \cdots + a_m CI_m}{a_1 RI_1 + a_2 RI_2 + \cdots + a_m RI_m}$$

CI_j: consistency index of each factor in B layer to the A_j

Results and discussion



Results and discussion

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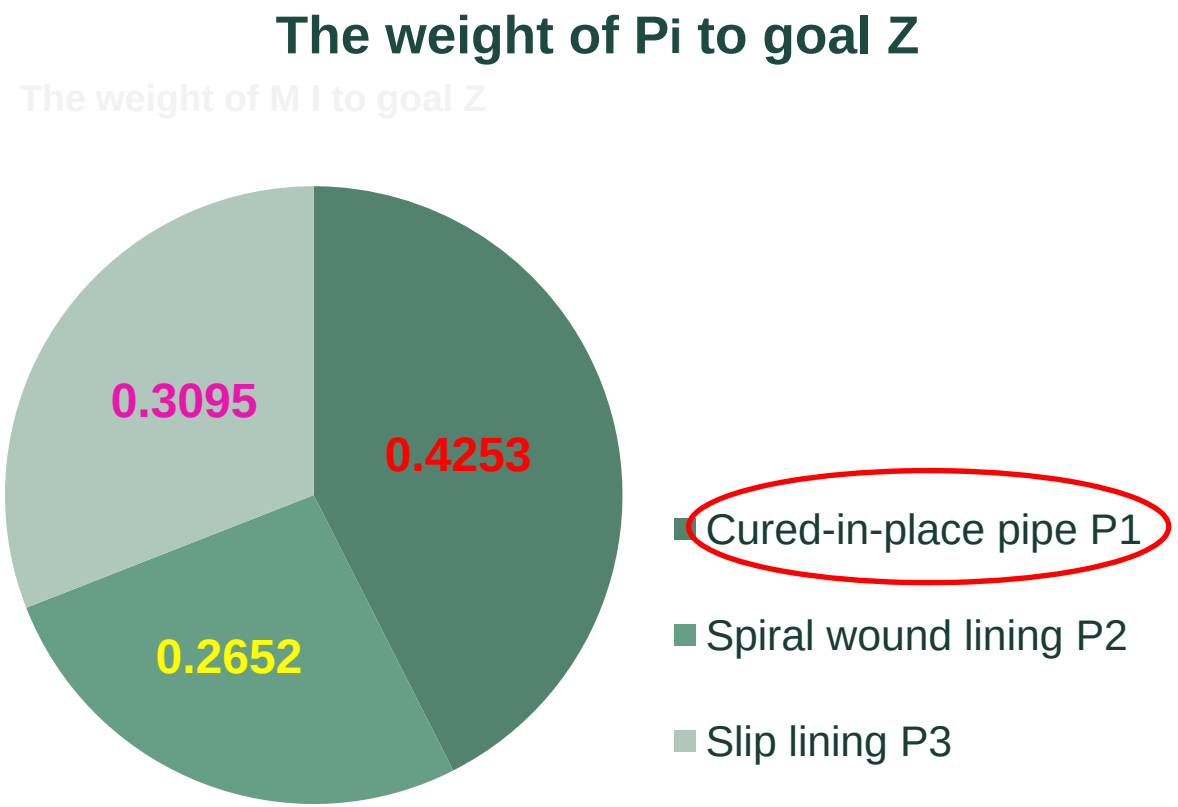

Results and discussion

By AHP

Construction condition, Site condition, Operation skill, Material cost, Social benefit, Environmental benefit etc.

AHP: well reflecting the real influence of various factors in trenchless technique selection

Cured-in-place pipe

From the technical perspective

Cured-in-place pipe

No require for pipe material and grouting;
Close joint between new and old pipes;
smooth surface, convenient construction;
flow performance improvement

Slip lining

cross-section area decrease,
grouting demand; obvious social effect

spiral wound lining

poor bearing capacity;
not suitable for pipe A

Conclusions

- The selection of trenchless rehabilitation technique is the problem involved in multi-criteria, multi-level and multi-target, therefore Analytic Hierarchy Process is the preferable decision-making method.
- In the study, 1-9 scaling is applied to construct the judgment matrix based on established hierarchical structure model. By means of constructing judgment matrix, sequencing by exponents and its consistency check, hierarchical population ordering and its consistency check, the result shows cured-in-place pipe is more suitable for trenchless rehabilitation of sewer pipelines whose diameters are between 300 to 600mm in the central urban area of Guangzhou City.


Thank you for your attention!