

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

## A case study in Guangzhou city

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Nov. 15, 2014





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# 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.

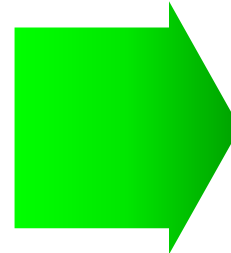
Used for over 30 years

Different pipe quality and  
Construction level

Overweight road load

Settling of ground

Corrosion of pipeline *etc.*



## Main damages:

Cracks

Joint displacement

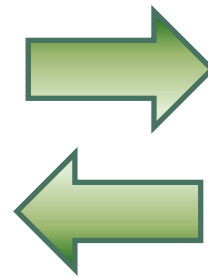
Open joints

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:

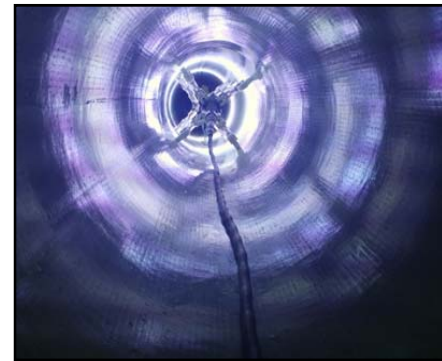
## Cured-in-place pipe:



**a. Pull-in lining**



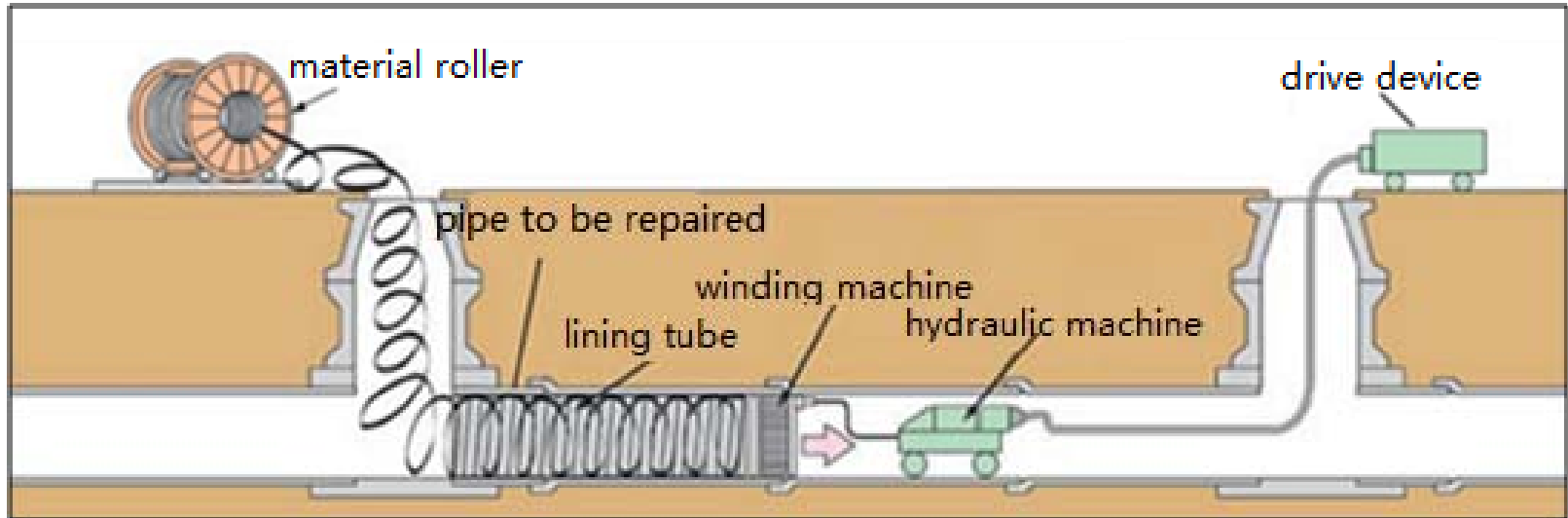
**b. Inversion lining**



**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.

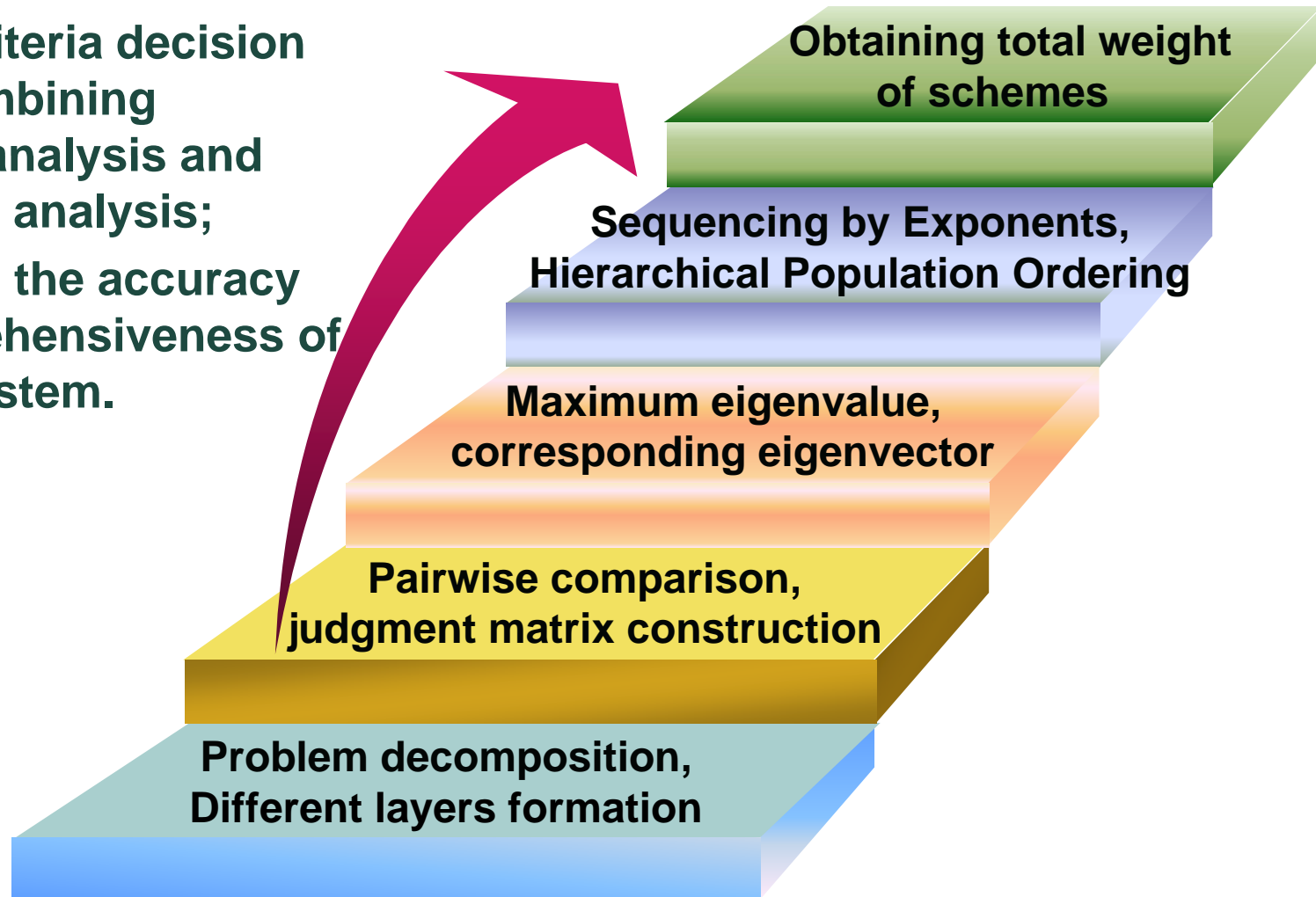


# Methodology

## Analytic Hierarchy Process (AHP)

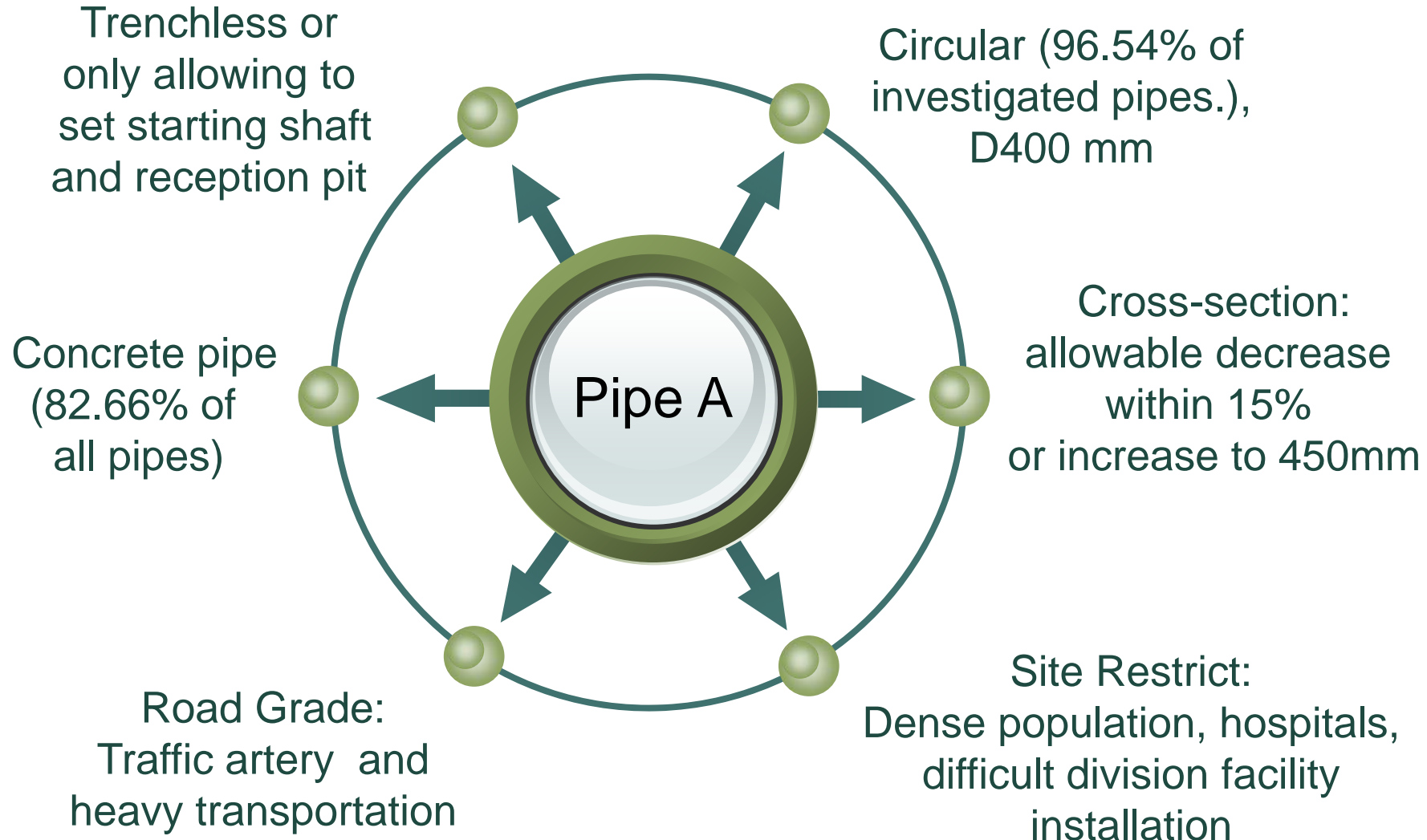
- A multi-criteria decision method combining qualitative analysis and quantitative analysis;
- Improving the accuracy and comprehensiveness of complex system.

## Best available technique



# Case analysis by AHP

## ➤ Typical Sewer to be Repaired: pipe A







# Case analysis by AHP

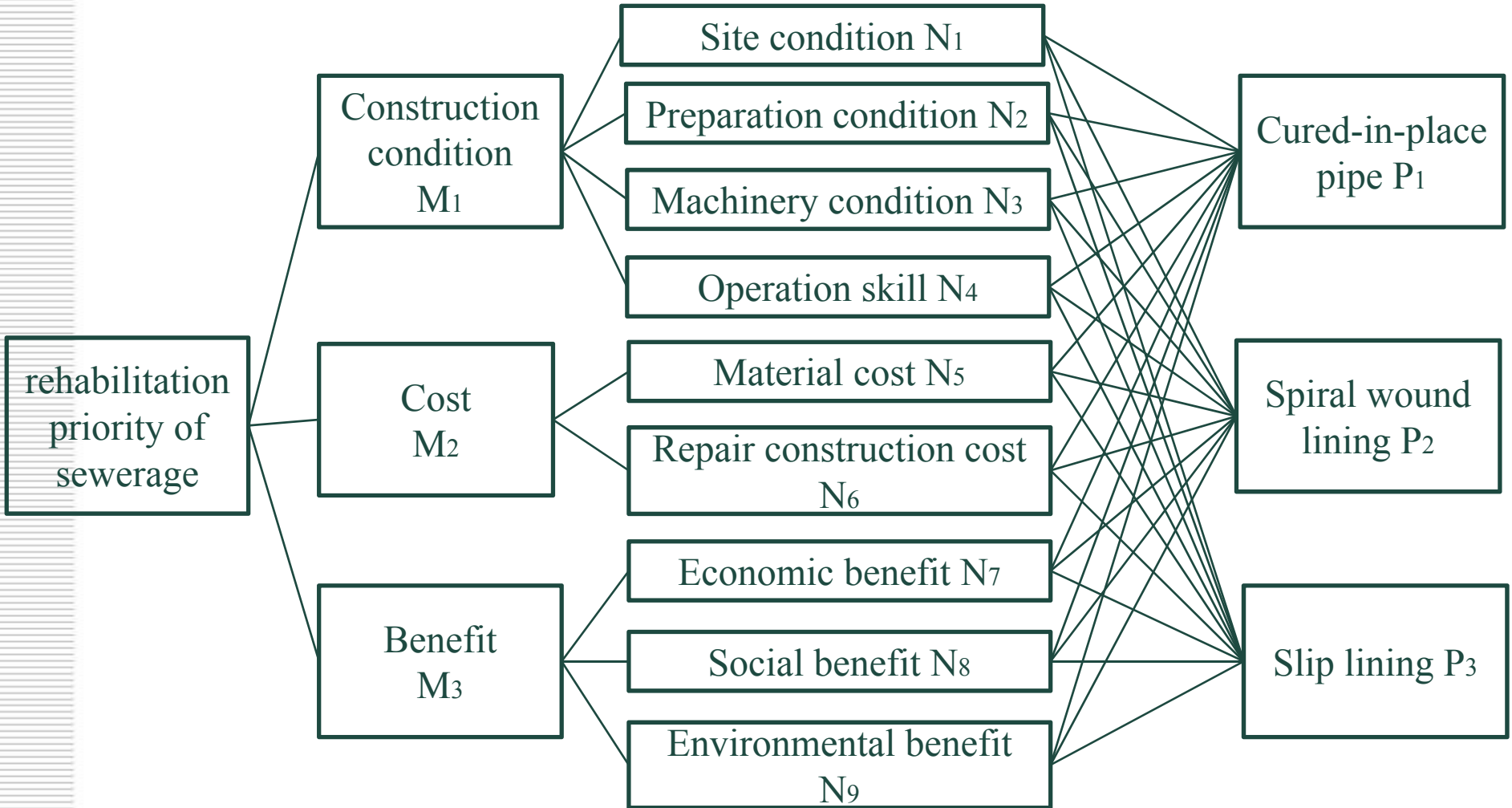
## ➤ AHP model of pipe A:

**Goal Z**

**Criteria M**

**Sub-criteria N**

**Alternatives P**





# 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 <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	Weight	CR Value
M <sub>1</sub>	1	3	2	0.5396	0.0079
M <sub>2</sub>	1/3	1	1/2	0.1634	
M <sub>3</sub>	1/2	2	1	0.2970	

The higher the weight, the more important the M<sub>i</sub> 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 :

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

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:

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

$a_j$ : 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:

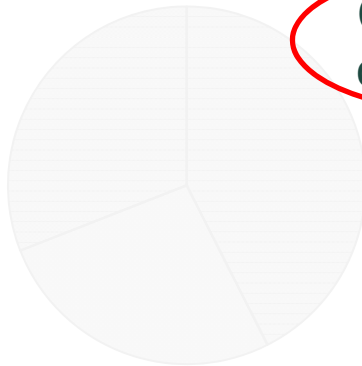
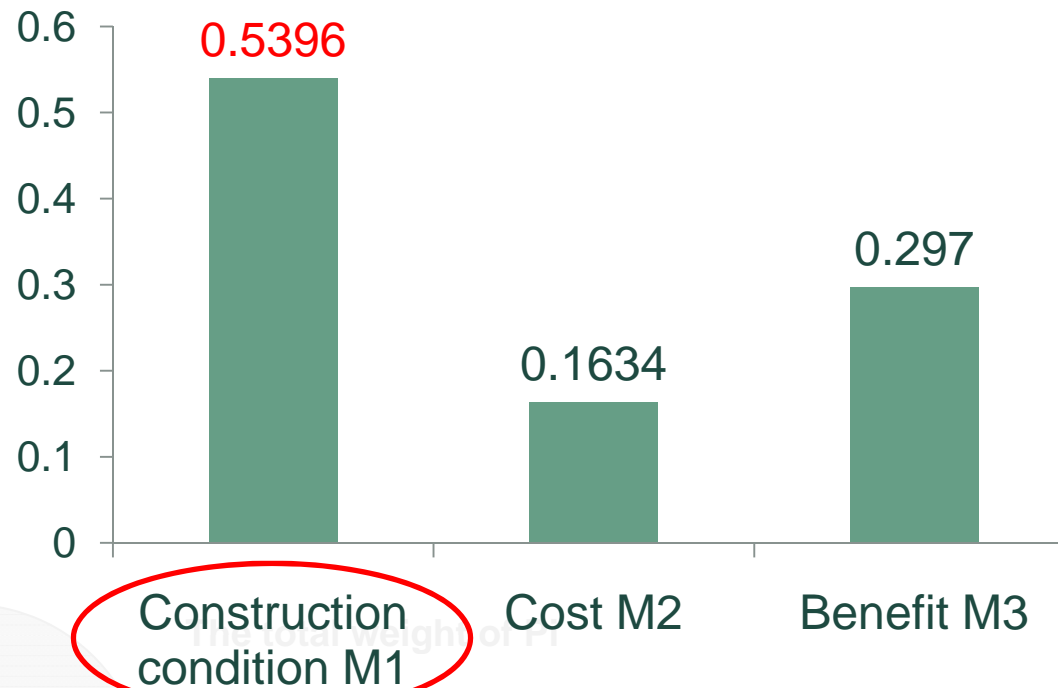
$$CR = \frac{a_1 CI_1 + a_2 CI_2 + \dots + a_m CI_m}{a_1 RI_1 + a_2 RI_2 + \dots + a_m RI_m}$$

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



# Results and discussion

## The weight of $M_i$ to goal Z

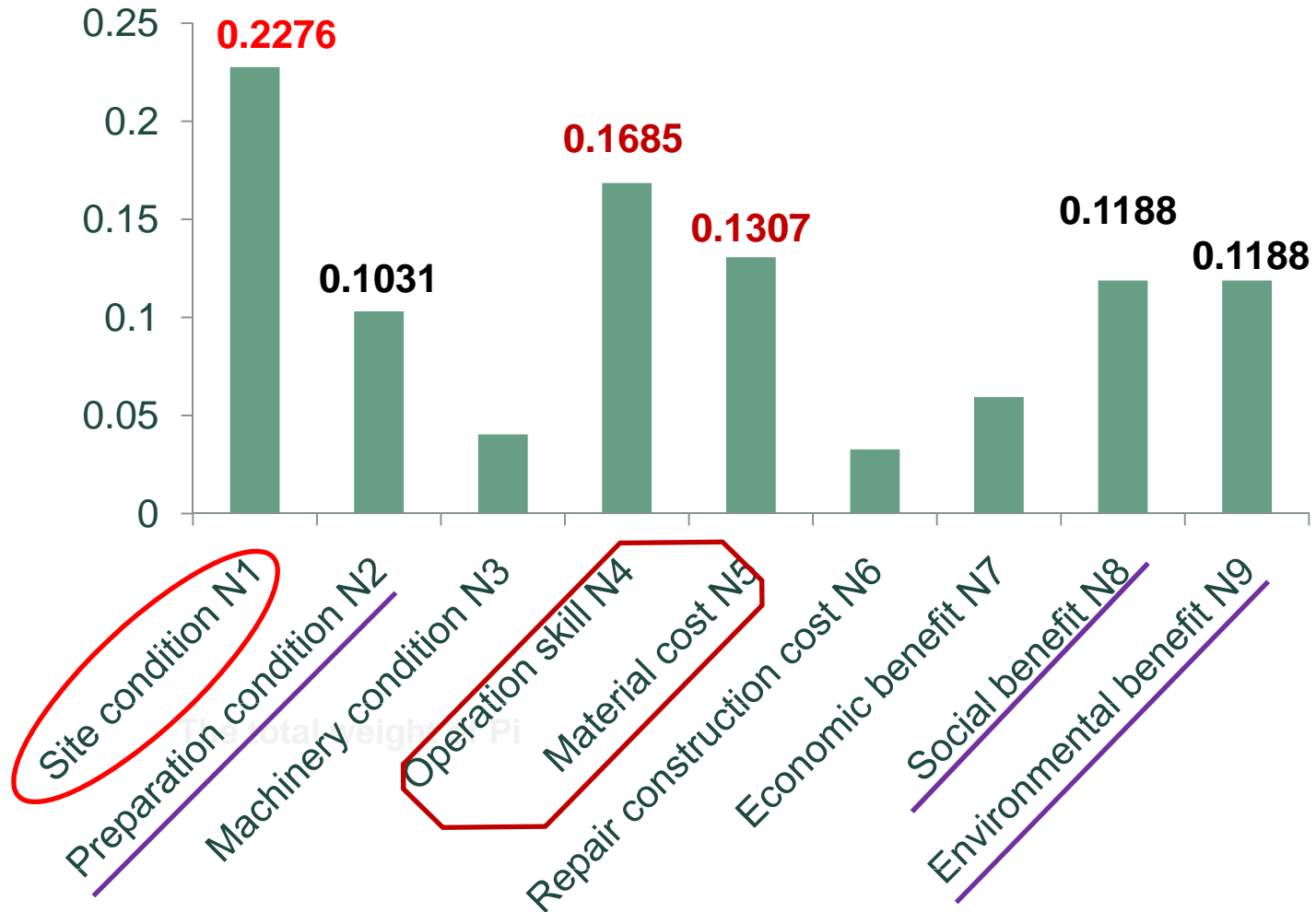


- Cured-in-place pipe P1
- Spiral wound lining P2
- Slip lining P3



# Results and discussion

## The weight of Ni to goal Z



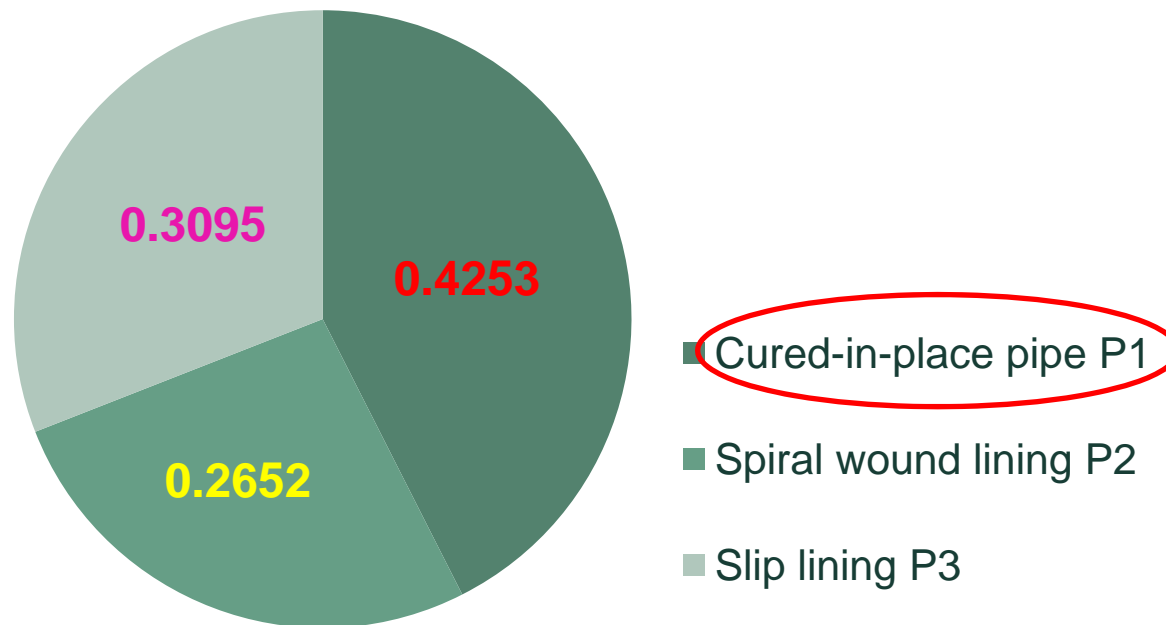
Total Weight = 1



# Results and discussion

## The weight of $P_i$ to goal Z

The weight of M I to goal Z





# Results and discussion

By AHP

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



Cured-in-place pipe

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

## 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



From the technical perspective

## 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!**