XVIII World Water Congress
International Water Resources Association (IWRA)

Location and scale optimization of polluted stormwater treatment plants in coal ports

Jiaqi Guo

Dalian University of Technology

大连理工大学 Dalian University Of Technology

XVIII WORLD WATER CONGRESS Water for All Harmony between Humans and Nature

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Introduction

Background

- **The coal port** plays an important role in the coal supply chain, coal storage, transportation services and so on.
- **Spraying operations** in coal ports consume large quantities of water in order to prevent pollution of the environment**.**
- The high cost of municipal water imposes a **financial burden on coal ports**.
- It is urgent to develop **non-conventional water resources** for coal ports**.**

Introduction

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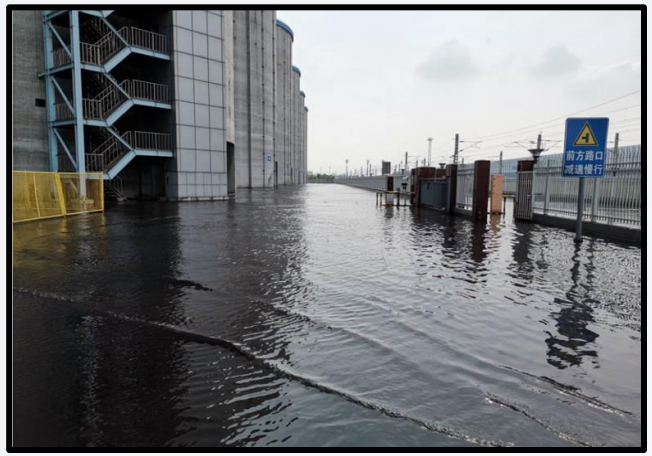
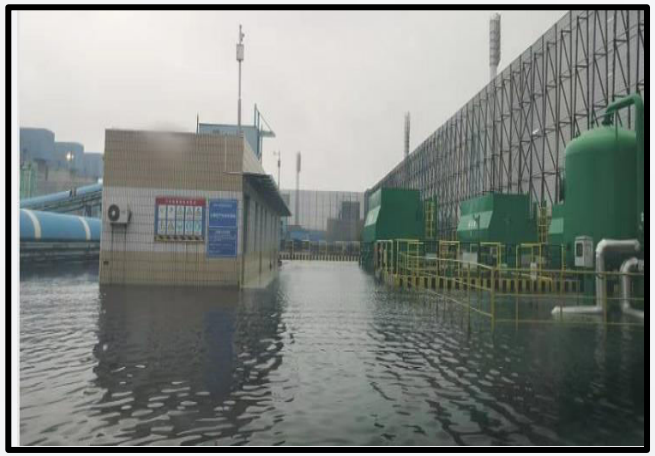
Background

- **Flooding in coal ports is frequent** due to the ban on discharging rainwater into the sea.
- **Coal-bearing stormwater** becomes one of the main unconventional water resources available to coal ports.
- **Layout of the coal-bearing stormwater treatment plant** has always been a problem for port side operators.

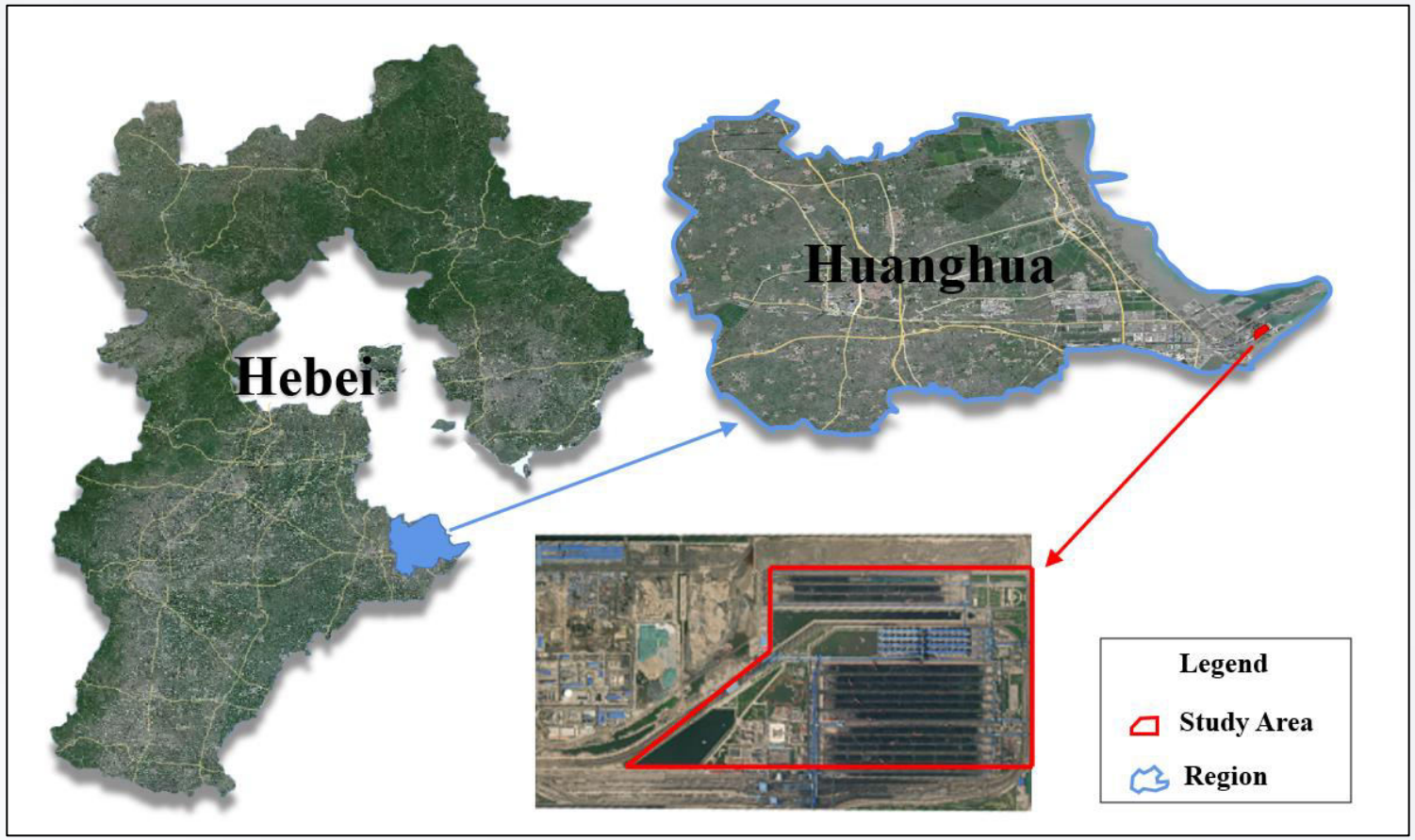




Previous Research

Representative Literature	Study content	Method
Liu et al. (2011)	Identifying site options for desalination plants, wastewater treatment plants and water reclamation plants for water-scarce islands	MIP+ CPLEX
Zeferino et al. (2017)	A discrete nonlinear robust optimization model for determining regional wastewater treatment system layout options, taking into account population uncertainty	SA
Altarabshehet al. (2018)	Propose a two-stage planning model for determining the number, location, capacity and service area of urban wastewater treatment facilities, taking into account population uncertainties	MCS+ NSGA-II
Rezaei et al. (2020)	Propose a multi-objective optimization model for determining the location of facilities, treatment capacity, configuration processes and customer allocation options	CPLEX
Zhang et al. (2023)	Propose a multi-objective optimization model for determining the optimal number, location and capacity of regional wastewater treatment plants	ACO

Study area

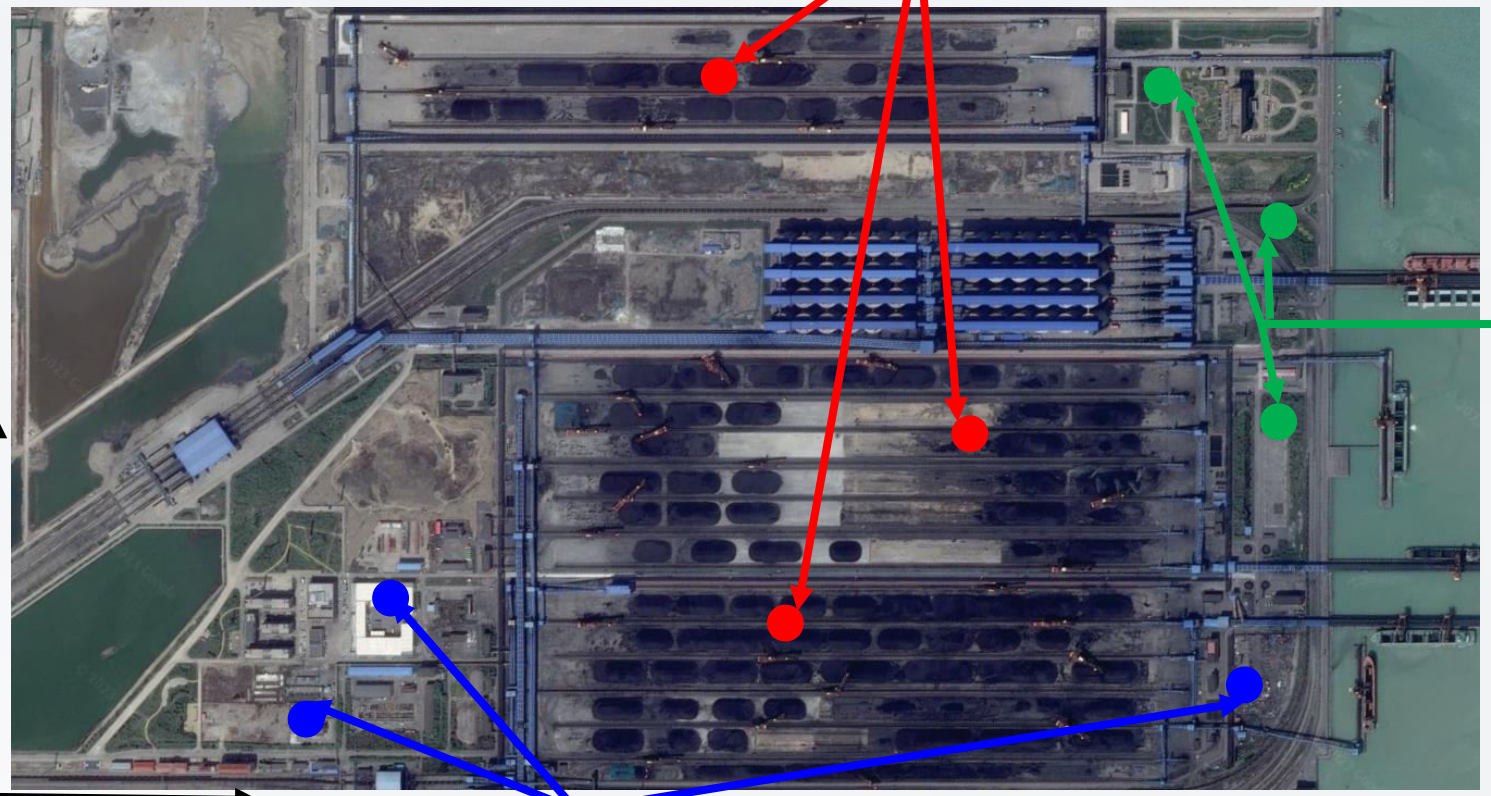


Huanghua Port

- Study port is a typical water-scarce regional port in China.
- Water prices in Hebei are expensive, especially in coal ports, reaching 10 CNY per cubic meter.
- In the past five years, the annual average total water consumption of Huanghua port reached about 5.10 million m3, and purchased municipal water accounted for 70% of the total consumption.

Methodology

Study area



Coal Stockyards

Green area

Buildings

EPA SWMM 5.2 (64-bit)

Methodology

Multi-objective optimization model

Objective functions :

$$\min C_{total} = \sum_{i \in I} \left(|x_i - x| + |y_i - y| \right) \cdot C_p + C_q$$

→ **Total cost** of construction and operation for stormwater treatment plants

$$\max CP = \frac{\sum_{i \in I} Q \cdot q^{-1}}{i_{\max}} \cdot 100\%$$

→ **Match level** between treatment plant capacity and treatment demand

Variables :

x : x-coordinate of the sewage treatment plant

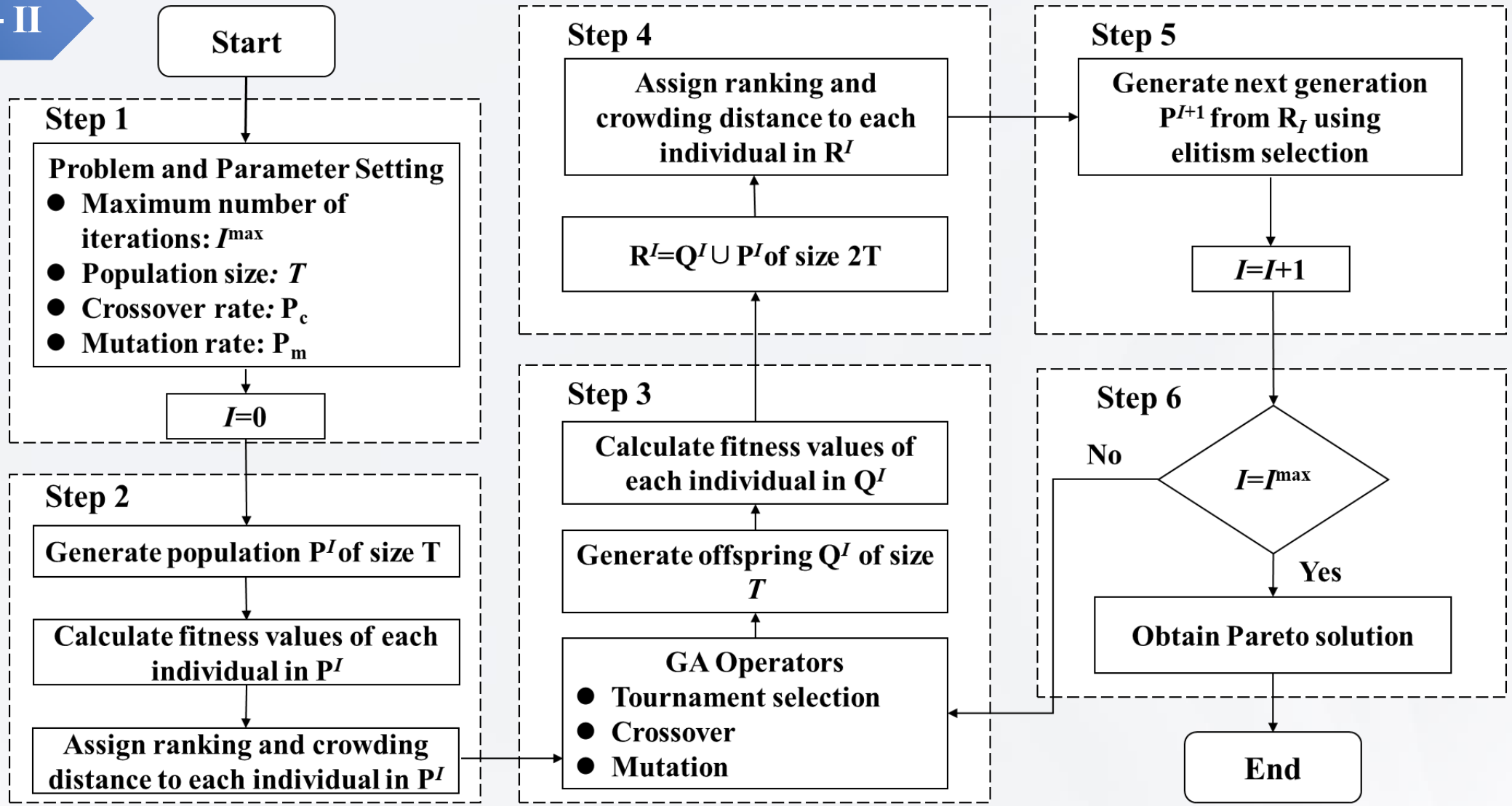
y : y-coordinate of the sewage treatment plant

q : the work efficiency of the sewage treatment plant

The constraints we considered include regional constraints and flow constraints, among others

Methodology

NSGA-II



Methodology

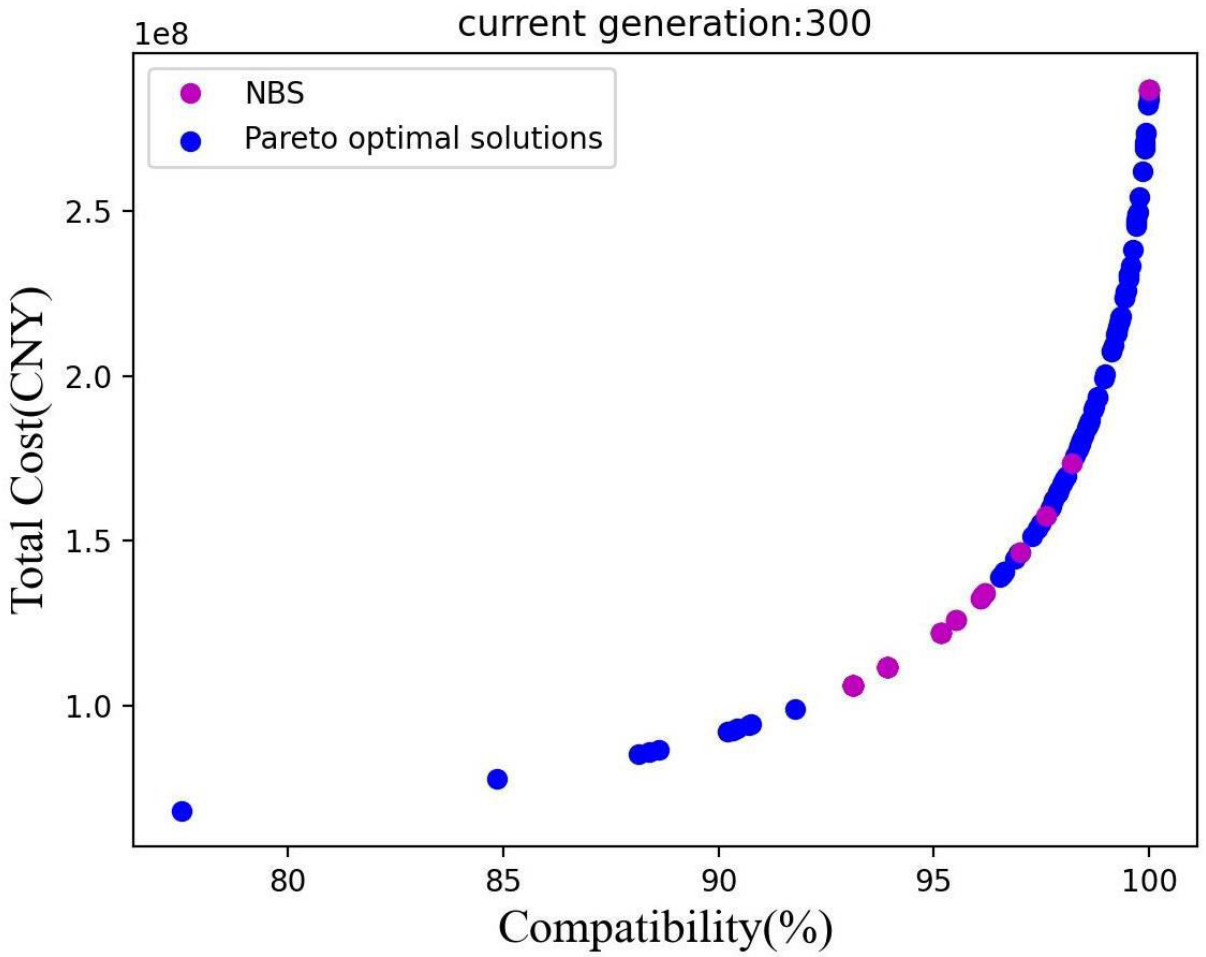
Nash bargaining Solution

$$d_\lambda(s)=\left[\left(\frac{f_1(s)-\min\limits_{s'\in\Omega}\{f_1(s')\}}{\max\limits_{s'\in\Omega}\{f_1(s')\}-\min\limits_{s'\in\Omega}\{f_1(s')\}}\right)^\lambda+\left(\frac{f_2(s)-\min\limits_{s'\in\Omega}\{f_2(s')\}}{\max\limits_{s'\in\Omega}\{f_2(s')\}-\min\limits_{s'\in\Omega}\{f_2(s')\}}\right)^\lambda\right]^{1/\lambda}\quad \forall s\in\Omega$$

$$s^*=\arg\min_{s\in\Omega} d_\lambda(s)$$

where Ω denotes the set on the Pareto frontier, and λ is a distance parameter. Given a certain value of λ, the point closest to the ideal point, namely, the NBS, can be determined by Eq.↵

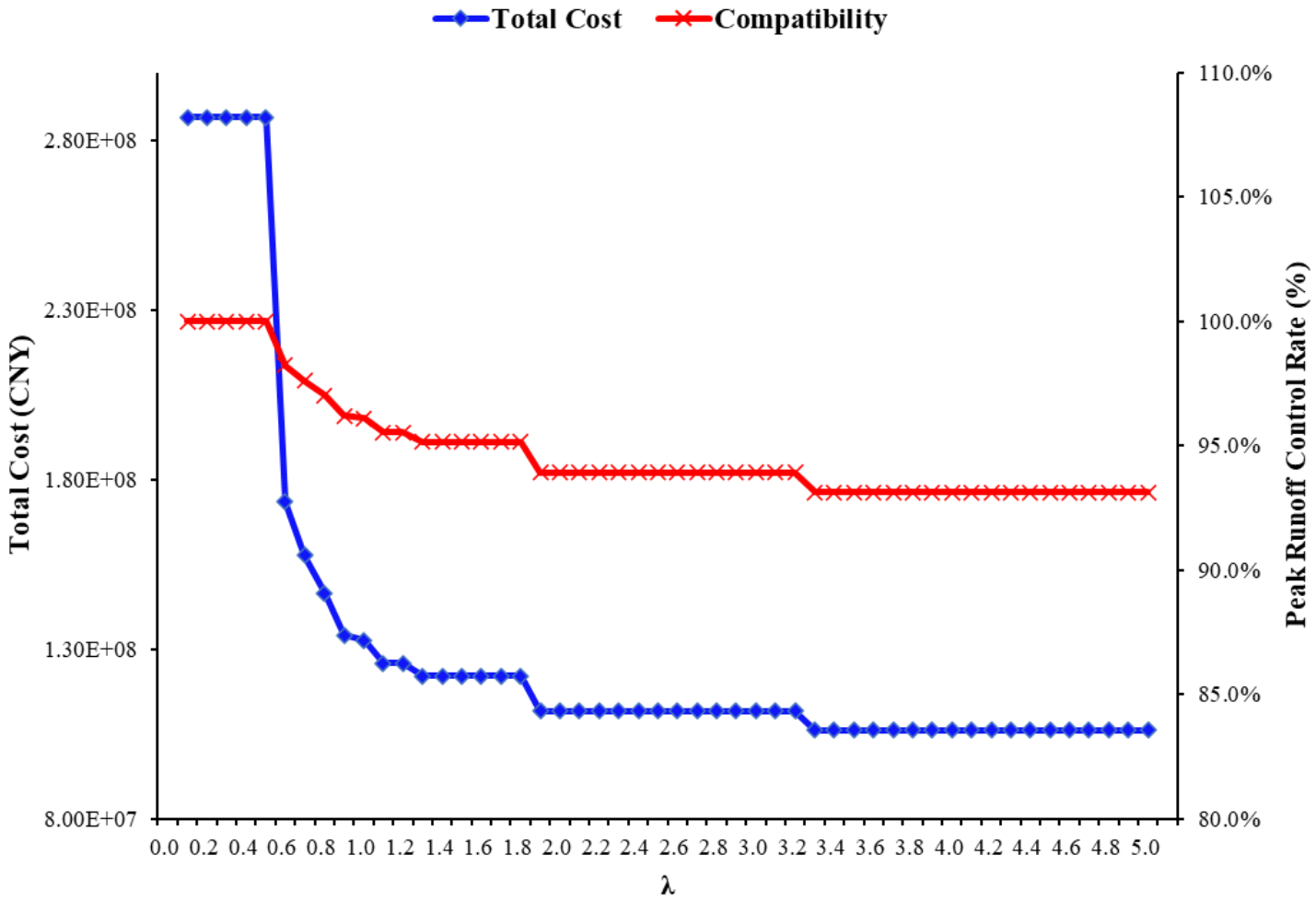
Results and discussion



- The Pareto solutions are distributed unevenly on the Pareto frontier due to the difference in the location and scale of opening polluted stormwater treatment plant. And a trade-off is required between the two proposed objectives . The compatibility increases as the expense of an increase in overall cost.
- In order to achieve a certain amount of compatibility, the polluted stormwater treatment plant will increase significantly.

When $3.1 \leq \lambda \leq 5.0$, this NBS can reconcile the conflict between the two objectives to the maximum extent and can be the solution of LIDFLP in coal port.

Results and discussion



- To balance the interests between the compatibility and the total cost of polluted stormwater treatment plant, this study proposed to find the NBS based on its proximity to the ideal solution captured by the distance parameter.
- When distance parameter is between 3.3 and 5.0 , this NBS can reconcile the conflict between the two objectives to the maximum extent and can be the solution in coal port.

Conclusion

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Conclusion and contribution

1. The problem was solved via a hybrid GA, in which the NSGA-II was adopted to obtain the Pareto frontier of the two objectives.

2. To help the port operator and the government determine the final solution from the Pareto frontier, this study adopted the concept of the NBS.

3. Our proposed method can provide a solution for the layout of the sewage treatment plant problem in a coal port, including the location of the plant and the working capacity of the plant..

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