Developing LPS downscale model and apply to Chinese iron and steel industry

Zhaoling Li[1], Tatsuya Hanaoka[1]
[1] Center for Social and Environmental Systems research, National Institute for Environmental Studies, Tsukuba 305-8506, Japan

1. Introduction

This research aims to establish a Down Scale Model to provide a decision tool for iron and steel (IS) plant planning at the national level. Given to the trend of rapid growth in iron and steel industry (ISI) in Southeast Asia countries and the possible downward trend in developed countries and China, there are two aspects should be considered in the model, which are the viability of optimal location for new iron and steel plant and the appropriate algorithm to shut up outdated facilities. The model is built up by:

- Analyzing the correlations among LPS location and evaluation factors, including transportation, natural condition, economy, policy and environmental criteria, based on historical data;
- Designing an evaluating algorithm of allocating LPS and verifying the possibility by adapt a case study;
- Allocating the air pollutants emissions on industrial level.

2. Research area

China's crude steel output experienced a rapid growth in last two decades, and lots of IS plants has been constructed. So, it is a typical case for analyzing the correlation between plant allocation and the criteria. On the other hand, China is eliminating the outdated equipment and plants to fix the problems in ISI, such as overcapacity and outdated technologies. Moreover, the crude steel demand is predicted to decrease after entering the late urbanization stage. Both of these two aspects could give a good reference for building up the Down Scale Model (Fig. 1).

Fig.1 Iron and steel plant in China based on Jams King 2018 database

3. Research framework

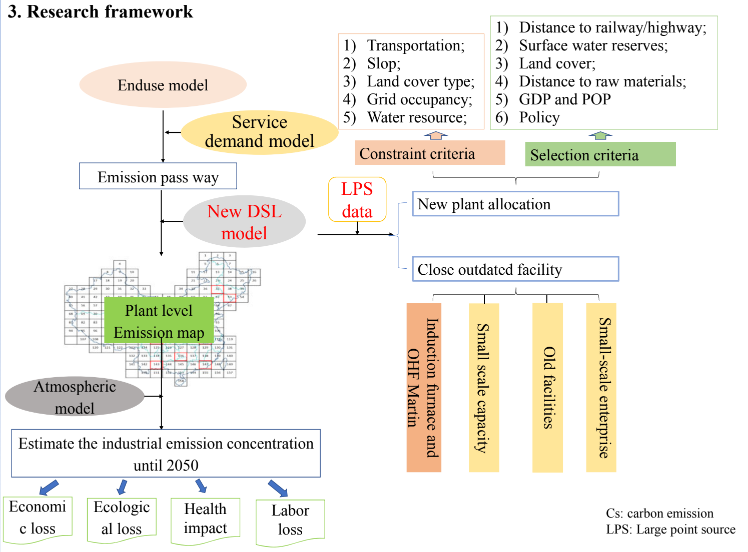


Fig. 2 Research framework

4. Algorithm construction

(1) New plant allocation

Databases showed in Tab. A-1 are attached in 30km×30km grid cells map, each cell representing an alternative location for a IS plant. Constraints criteria is to exclude the infeasible sites. Selection parameter is decided based on the condition of existing plants and the result is shown in Fig. 3.

Selection criteria is using for ranking the priority of each appropriate sites (remaining grids in Fig. 3) according to spatial multi-criteria decision making. Sorting principles of some selection criteria are showed in Tab. 1.

Tab. 1 Sorting principles of some selection criteria

Evaluation criterial	Sorting principle
Distance to railway/highway	the closer, the better
Surface water reserves	the more, the better
Distance to raw materials	the closer, the better
GDP and POP	S1: the higher, the better S2: the lower, the better

Fig. 3 Appropriate locations for new iron and steel plant

For the grid ranking based on land cover type, there are four principles that need to be considered. ① grid occupancy, ②cropland and ③grassland areas: the higher, the better; ④urban area: the lower, the better.

$$Ar_g^{lt} = \sum_l Ar_g^l \quad (l = 10,11,40,130,190,200) \quad (1)$$

$$R_g^l = \frac{Ar_g^l}{Ar_g^{lt}} \quad (l = 10,11,40,130,190,200) \quad (2)$$

$$R_g^{lt} = \frac{Ar_g^{lt}}{Ar_g} \quad (l = 10,11,40,130,190,200) \quad (3)$$

$$Sn_g^{lu} = Sn_g^{lt} + \sum Sn_g^l \quad (l = 10,130,190,) \quad (4)$$

$$Sn_g = Sn_g^{dt} + Sn_g^{sw} + Sn_g^{lu} + Sn_g^{dr} + Sn_g^{GDP/POP}(high/low) \quad (5)$$

Ar_g^l: area of each land cover type (l) within one grid (g);
Ar_g: area of grid;
R: ratio of each land use type and the total area within one grid;
Sn: ranking of each land use type and give serial number based on the ratio;
Sn_g^{lu}: ranking of each grid based on the sum of serial number of total area and each land cover type, lower is better, and give each grid a serial number accordingly;

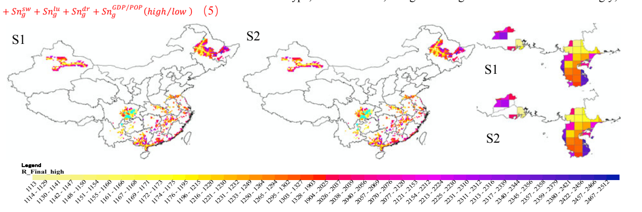


Fig. 4 Final ranking of each grid based on six criteria proposed in this research. S1: higher GDP/POP, the better; S2: lower GDP/POP, the better

(2) Close facility

Currently, over capacity is one of the most important problem in China with only about 70% of operating ratio, far below the average level in developed countries. Domestic steel demand may decrease after the late of urbanization in China. Therefore, it is necessary to figure out an algorithm to remove the redundant capacity. The final target is to achieve 80% operating ratio in 2020.

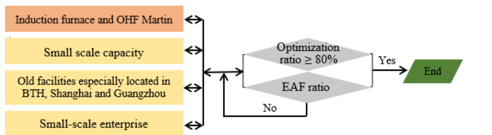


Fig. 5 Framework about how to close the existing facilities

5. Case study

Crude steel demand based on SSP2 scenario will peak in 2030 and then decrease (Tab. 2). In this case, we should consider both new plants construction and facility shut down in China until 2050. Moreover, electric arc furnace (EAF) has better effect on promoting energy conservation and clean production than basic oxygen furnace (BOF). Thus, production structure upgrading should be considered during the industrial optimization. Average capacity of iron and steel plant built after 2000 is 5397.65 kt. This result will be used to decide the number of new plant.

Tab. 2 Future demand of crude steel in China in SSP2 scenario

	2015	2020	2025	2030	2035	2040	2045	2050
Demand in SSP2 (kt)	820265	981726	1066304	1074090	1032735	975297	912056	844404
Import amount (kt)	13178	13178	13178	13178	13178	13178	13178	13178
Domestic production (kt)	807087	968548	1053126	1060912	1019557	962119	898878	831226
Current capacity (kt)		973165	1054130	1064925	1021358	964580	897952	833404
Increasing demand (kt)		27769	79960	6782	-45368	-59239	-65702	-66726
Ferrous scrap stock (kt)		261814	368022	435130	486812	517658	528702	525033
EAF capacity demand (kt)		170262	239331	282972	316582	336642	343824	341438
Number of new plant		6	15	2	0	0	0	0
BOF capacity ("-" means BTE)		-22072.84	17250.87	-36859.49	-96595.31	-78279	-72233	-64103
Operating ratio (OR) (%)		88.63	89.73	89.57	89.36	88.743	88.34	87.22

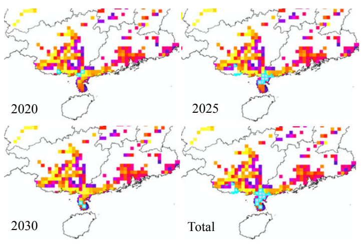


Fig. 6 Location of new plants from 2020 to 2030

~2020: close outdated facilities + new plants +BTE

After reaching the 80% OR in 2020. The remaining capacity is a little bit lower than the demand. Therefore, 6 new plans should be built up. At the same time, due to the quick increase of recyclable scrap, part of BOF need to transfer to EAF (Fig.7).

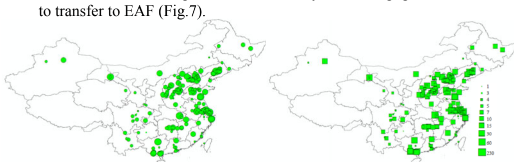


Fig. 7 Plants location/capacity and the CO_2 emissions in 2020

2026~2030: New plants + BTE

2 new plant will be built for the slight increasing demand. Scrap is still remaining rapid growth. So, some BOF still need to be converted to EAF (Fig.9).

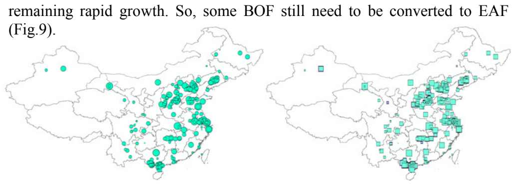


Fig. 8 Plants location/capacity and the CO_2 emissions in 2030

2036~2040: Close old facilities + BTE

Crude steel demand will decrease. Whereas, scrap is still remaining rapid growth. So, some BOF still need to be both closed and converted to EAF (Fig.7).

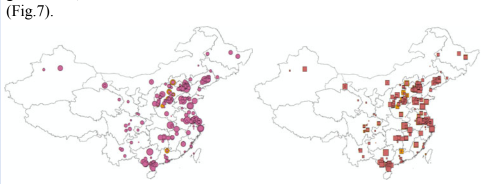


Fig. 9 Plants location/capacity and the CO_2 emissions in 2040

2046~2050: Close old facilities

Both crude steel demand and recyclable scrap are decreasing. So, outdated BOF and EAF need to be (Fig.13).

Fig. 10 Plants location/capacity and the CO_2 emissions in 2045

Comparison between original data and result

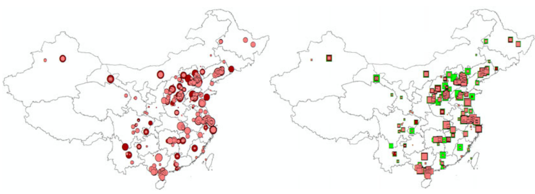


Fig. 14 Differences of plants location/capacity and the CO_2 emissions between JK database and estimation results in 2050

6. Conclusion

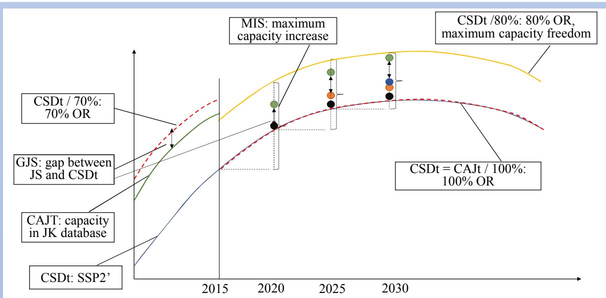
The aim of this research is to design, apply and evaluate an integrate framework for responding to dynamic development changes of the iron and steel industry, and then construct an emission map at the plant level. For this aim, a GIS-based multi-criteria decision analysis procedure has been developed and then applied to China. Finally, we found that:

1) The evaluating algorithms for both selecting the most appropriate sites for the new plant and eliminating the outdated facilities are able to handle the multi-criteria for multiple objectives that need to be considered when constructing a new iron and steel plant and closing old furnaces;

2) Industrial upgrading also performs well by transforming BOF to relatively environmental friendly EAF route. The recyclable scrap is estimated and can be just completely consumed.

3) Large amount of capacity in Beijing-Tianjin-Hebei region are closed, while most capacity in Shanghai are remained, which indicating a different level of facility and production in these two old steel bases.

4) The center of crude steel production will move to western China and southern China. At the same time, emission will also transfer to those two regions, which needs to arouse our attention.



Hypothesis:
1. crude steel imported form other countries in 2015 must be imported unless there is a technological breakthrough;
2. Construction time of new plant is not considered in this research;
3. Scrap generated in 2015 can be total reused by current EAF facilities;
4. BOF is the first choice to be closed, EAF will not be reduced after during 2020-2045;

Estimation method of recyclable scrap:

$O_{fs}(t) = (0.08 + 0.06)O_{cru}(t) + 0.32O_{cru}(t-15) + 0.6O_{cru}(t-50)$