

Multi-criteria decision analysis (MCDA) of iron making technology in Thailand

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Abstract:

The purpose of this study is to evaluate and prioritize iron making technology in Thailand by using Multi-Criteria Decision Analysis (MCDA). The scope of assessment was focused on three iron making technologies are blast furnace (BF), corex and midrex. Three iron making technologies were evaluated by using bipolar analytical hierarchy process (BAHP) based on three main criteria and nine sub-criteria. The qualitative data and quantitative data were collected from government sector, private sector, education sector and institute sector. The qualitative data of relative preferences were changed to quantitative data by expert judgment following classical AHP method. The results showed that in economic criteria BF technology had the positive preference due to high net profit. The most preferences of iron making technology in terms of environmental concerns and technology criteria belonged to midrex technology due to use natural gas as fuel as well as lower environmental impact. The results from final evaluations based on technology, economic and environment aspects using the bipolar analytical hierarchy process (BAHP) exhibited that BF technology was the most preference of iron making technology in Thailand (48%), followed by midrex (28%) and corex (24%) respectively.

Keywords: Multi-Criteria Decision Analysis; MCDA; iron making technology; Thailand

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1. Introduction

The iron and steel industry is one of the largest energy consuming manufacturing sectors and one of the most important sources of CO₂ emission in the world. According to the Intergovernmental Panel on Climate Change (IPCC), the iron and steel industry accounts for between 3-4% of total world greenhouse gas emissions (IPCC, 2006). Especially, iron making process is contributed the most of CO₂ emission by 91% (POSCO, 2008). The iron making technologies in the world have four routes: blast furnace (BF) is the most widely used (57.6%) followed by electric arc furnace (EAF) 37.9%, direct reduction 4.1% and smelting reduction 0.4%, respectively (Gupta and Sahajwalla, 2005). Currently, there is no upstream iron and steel industry in Thailand. Most of steel processing technology in Thailand is electrical arc furnace (EAF) using steel scrap as a raw material. The statistic report indicated that amount of crude steel produced in Thailand is not sufficient to its consumption due to no upstream steel industry. In 2011, the crude steel production was 4.25 million tons; however the steel demand was up to 14.7 million tons (ISIT, 2012). Due to the high domestic demand of iron and steel products, the Thailand Board of Investment (BOI) announced the promotion of the upstream iron manufacturing in Thailand (BOI, 2007) and proposed three plausible scenarios which were without integrated steel plant (baseline scenario), with a traditional integrated BF-BOF route and with an alternative integrated DR-EAF route in the master plan of energy management for Thailand iron and steel industry (ISIT, 2012). The establishment of upstream iron industry has the benefits in terms of economic. However, in environmental aspects the iron production causes adverse environmental impacts such as high energy consumption and greenhouse gas (GHGs) emission. Thus, this research aims to evaluate and prioritize iron making technology in Thailand by using Multi-Criteria Decision Analysis MCDA (Bipolar Approach). The results from this study will be useful technical information for policy planning in iron and steel industry in the future.

2. Material and methods

2.1. The structure of iron making technologies in Thailand.

The scope of assessment was focused on three iron making technologies are blast furnace (BF), corex and midrex as shown in Fig.1. Three iron making technologies were evaluated by using bipolar analytical hierarchy process (BAHP) based on three main criteria and nine sub-criteria. The main criteria consisted of economic, environmental and technology. Sub-criteria of economic consisted of direct cost, indirect cost, direct benefit and indirect benefit. Sub-criteria of environmental consisted of energy consumption, greenhouse gas (GHG) emission and resource depletion. Sub-criteria of technology consisted of barrier of materials and complexity of operation.

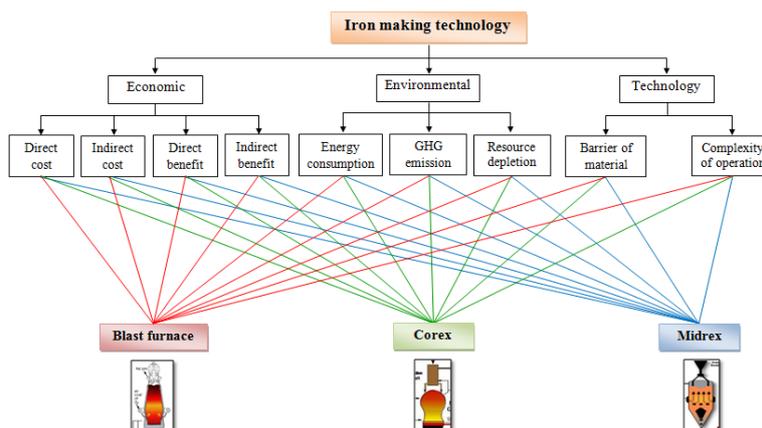


Fig. 1 The structure of iron making technology in Thailand.

2.2 Collection of iron making technology data

The qualitative data and quantitative data were collected in this study. The quantitative data of economic and environmental come from a literature review. The qualitative data were collected from fifteen experts in government sector, private sector, education sector and institute sector. The qualitative data of relative preferences were changed to quantitative data by expert judgment following classical AHP method. The Saaty's fundamental scale of 1–9 was used to assess the intensity of preference between two elements (Saaty, 2008).

2.3 The consistency ratio (CR) test

The consistency ratio (CR) index is important for the decision maker to assure that judgments were consistent and the final decision is made well. If the CR exceeds 0.1, the expert judgments are untrustworthy because they are too close for comfort to randomness and the exercise is valueless or must be repeated. The equation for calculation CR is shown in Eqs. (1)-(2) below.

$$C.I. = (\lambda_{\max} - n) / (n - 1) \quad (1)$$

$$C.R. = C.I. / R.I. \quad (2)$$

Table 1 Random Consistency Index (R.I.)

n	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Where:

C.R. is consistency ratio, C.I. is consistency index

n is size of squared matrix, λ_{\max} is eigenvalue (calculated from MATLAB program)

2.4. Calculation of the bipolar analytical hierarchy process (BAHP).

The bipolar analytical hierarchy process (BAHP) is a multi-criteria decision tool improved from classical AHP by BAHP. The benefit of BAHP is that it can reflect of both positive and negative desirability as opposed to the strictly positive of the classical AHP. The step of BAHP calculation is shown in Fig. 2. The final results come from multiply bipolar matrix by criteria weight matrix.

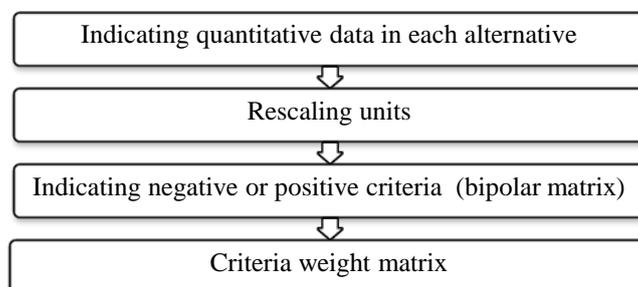


Fig. 2 The steps of bipolar analytical hierarchy process (BAHP).

The present value of money in economic criteria is converted to the future value following Eq. (3). The money in unit of USD is changed to the unit of Thai baht.

$$FV = PV \times (1+r)^t \quad (3)$$

Where:

FV is future value of money, PV is present value of money, r is interest rate average from 1977-2013 (4.66%)

t is time period, 1USD = 30.22 baht, 1Euro = 40.23 baht (BOI, 2013)

3. Results and Discussion

The results in Fig. 3(a) showed that BF technology had the positive preference in economic criteria due to high net profit. Whilst corex and midrex technologies had the negative preference in economic criteria due to their high investment cost. Especially, high quality of raw material is required for midrex resulting in high cost of raw material. In environmental criteria, the results indicated that all iron making technologies had the negative preference as shown in Fig. 3(b) due to the effect of resource depletion, energy consumption and greenhouse gas emission. Even though all environmental criteria are negative preferences, the most preferences of iron making technology in terms of environmental concerns belonged to midrex followed by BF and corex, respectively. Midrex exhibits less environmental impacts because it uses natural gas while BF and corex use coke and coal as a reducing agent. The corex process differs from BF process in that it uses non-coking coal. As a result, coking plant is not necessary. However, the primary energy consumption in smelting reduction process and greenhouse gas emission of corex is higher than that of BF. Results of technology assessment are presented in Fig. 3(c). The most preference of iron making technology belonged to midrex followed by corex and BF, respectively. Analysis of technology assessment was considered on two subcriteria: barrier of raw material acquisition and complexity of operation. According to expert judgement, midrex has the highest barrier of raw material because the process uses natural gas as a reducing agent which is not suitable for countries that have high gas price, like Thailand. However, midrex has lowest complexity of operation. While corex has the lowest barrier of raw material, it has highest complexity of operation because corex has two separate process reactors which are the reduction shaft and the melter gasifier. The final evaluations based on technology, economic and environment aspects using bipolar analytical hierarchy process (BAHP) exhibited that BF technology was the most preference of iron making technology in Thailand, followed by midrex and corex as shown in Fig. 3(d). The results in negative values were converted

to positive values by normalization (one minus the absolute value of negative result and then divided by summation of all values).

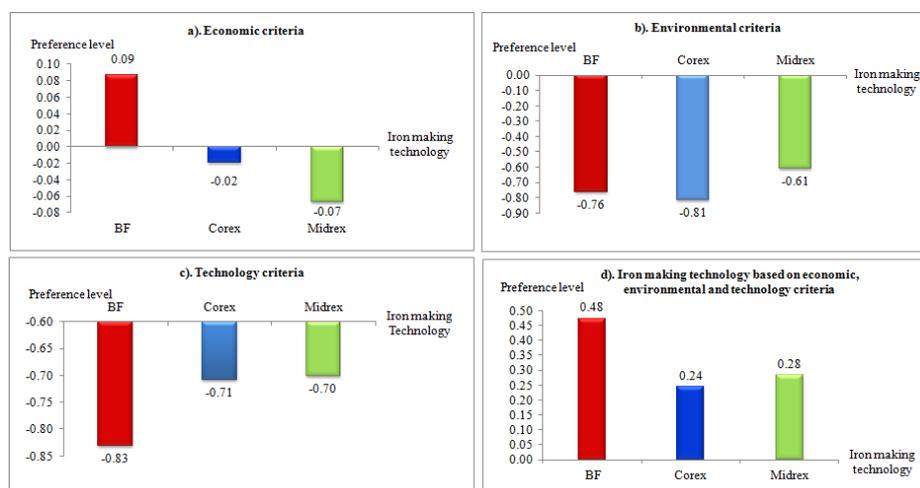


Fig. 3 The preference levels of iron making technology in Thailand.

4. Conclusion

In this study, three iron making technologies such as blast furnace (BF), corex and midrex were evaluated and prioritized by using Multi-Criteria Decision Analysis MCDA (Bipolar Approach). The results showed that BF technology was the most preference of iron making technology in Thailand, followed by midrex and corex respectively. Even though midrex technology uses natural gas as a reducing agent which results in lower pollutant emissions, it is not suitable for countries that have high gas prices. While corex is environmentally friendly production of hot metal compared to BF, the process is still less flexible and limited for large-scale production. Accordingly, BF is recommended for suitable iron and steel production in Thailand. To overcome the limitations of BF technology in Thailand, the best practices for BF technology should be further explored and detailed feasibility study should be investigated.

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6. References

- Gupta, S. and Sahajwalla, V. 2005. The scope for fuel rate reduction in iron making. Australia: The university of New South Wales.
- Intergovernmental Panel on Climate Change (IPCC). 2006. Emission factor database [Online]. Available at: http://www.ipcc-nggip.iges.or.jp/EFDB/find_ef.php [Accessed on 18 September 2013].
- Iron and Steel Institute of Thailand (ISIT). 2012. Master plan for energy management in Iron and steel industry in Thailand (pp. 8-22). Bangkok: Iron and Steel Institute of Thailand.
- POSCO. 2008. CO₂ Breakthrough Solutions in Steel Industry [Online]. Available at: <http://www.singg.org/inc/download.asp?UPFILE=%5B4-3%5D.pdf> [Accessed on 8 August 2013].
- Saaty, L.T. 2008. Decision making with the analytic hierarchy. USA: Inderscience Enterprises Ltd.
- The Board of Investment of Thailand (BOI). 2007. Thailand Investment Review [Online]. Available at: <http://www.mda.co.th/jan08/ThaiSteelIndustry.pdf> [Accessed on 5 August 2012].
- The Board of Investment of Thailand (BOI). 2013. Interest rate and exchange rate [Online]. Available at: <http://www.boi.go.th/index.php?page=index> [Accessed on 22 December 2013].