Research on China Airport Performance Evaluation of Energy Conservation and Emission Reduction Based on Data Envelopment Analysis Model

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Abstract. With study on 15 China airports (groups) that were funded by the special funds for energy conservation and emission reduction in civil aviation, using the SE-DEA model as research tool, the energy conservation and emission reduction efficiency of the sampled enterprises were analyzed. More than half of the airport units did not achieve DEA efficiency, mainly resulted from the simultaneous technical inefficiency and scale inefficiency. All units that failed to meet the standard should increase the quantity of electricity conservation. In the future, the scale of project output should be expanded in resource allocation in the development of China green airports, strengthening research and application of new technology and new method. This study is of certain guiding significance for the scientific allocation of financial resources and the construction of green civil aviation.

1. Research Background
Airport is an important infrastructure for the air transport system, and the construction scale and number of China airports continue to grow rapidly. By the end of 2017, there were 229 certificated transport airports in China, with an increase of 11 from the end of last year. However, many environmental diseconomies have been generated by the airports in actual economic activities, such as high energy consumption, airport noise, greenhouse gas emissions, and low biological care which are deviated from the social responsibility of the enterprise to maintain the ecological environment. To adhere to the green development of civil aviation, we must firmly establish green and low-carbon theories, strengthen the awareness of energy conservation and emission reduction, and enhance the mission sense of sustainable development for civil aviation.

International and regional organizations such as the International Air Transport Association (IATA), the International Civil Aviation Organization (ICAO) and the European Union have proposed higher energy conservation and emission reductions for civil aviation. The external situation of energy conservation and emission reduction faced by civil aviation in China is very serious. To achieve the set goals of energy conservation and emission reduction, new technologies and new energy sources, renovated facilities and equipment, and innovative management models must be applied. The research of these projects requires a large amount of investment, and many projects have long payback periods, without obvious economic benefits in a short period of time, resulting in weak initiatives of the enterprise investment. In order to stimulate and promote the investment enthusiasm of civil aviation transport enterprises and institutions in energy conservation and emission reduction projects, the Civil
Aviation Administration of China has established a special fund for energy conservation and emission reduction of civil aviation, and supported the energy conservation and emission reduction projects with outstanding effects in the form of special financial funds, in favor of the civil aviation transportation industry including the airport, and the sustainable development of the economic society. The performance evaluation of the projects supported by the civil aviation special fund is not only to sort out and summarize the development of energy conservation and emission reduction projects, but also to determine the project categories or fields that should be invested in the future by the special fund for airport energy conservation and emission reduction, and to maximize the benefits of the special funds for energy conservation and emission reduction in civil aviation.

2. Research review

The studies on the systematic evaluation of environmental treatment effects and investment scale and efficiency, have been started in the 1960s, widely using the input-output mathematical induction method. Cumberland (1966), Daly (1968), and Leontief (1970) analyzed the quantitative relationship between environment and economic activities by introducing environmental factors into the input-output model and expanding that. Xu Jie (2007), Tao Min (2011, 2012), and Liu Libo (2016) utilized the DEA method to analyze the investment efficiency and key influence factors of environmental treatment in China. An implementation capability evaluation system of energy conservation and emission reduction for enterprises was built by Agusdinata (2011) from five aspects: research and development support capability, emergency response capability, guarantee capability, control capability and cost situation. Chen Yuxiu and Yu Jian (2017), through the construction of input-output index system of different project categories and “Conservation and Emission Reduction” investment efficiency evaluation model of China’s civil aviation industry based on super-efficiency DEA Model, evaluated the investment efficiency of energy conservation and emission reduction projects in the civil aviation industry in Central and South China.

In short, nowadays the literatures on the performance evaluation of environment treatment pay less attention to the civil aviation system, and even rare literatures involve airport project evaluation. The current literatures are difficult to directly measure the effects of energy use by airport, emission situation, and energy conservation and emission reduction, and could not guide the civil aviation transportation enterprises in the management of assessment and optimization in the energy conservation and emission reduction process.

3. Evaluation indexes

In accordance with the principles of systematization, scientificity, measurability and comparability, dynamic continuity, combined with the requirements of “Notice of the State Council’s approval of the implementation plan and method for the statistical monitoring and assessment of energy conservation and emission reduction”, and meanwhile full considering the requirements of the regulations, standards and documentation related to energy conservation and emission reduction of civil aviation enterprises and the industrial characteristics of the airport industry, reasonable evaluation indicators were selected. The total investment in energy conservation and emission reduction of the project and the increase in energy input were mainly selected as the input indicators, while the output indicators are mainly the savings of various energy indexes, with calculation method shown in Table 1.

| Project of airport energy conservation | Category of energy/mission | Quantity calculation of energy conservation and emission reduction |
|--------------------------------------|---------------------------|-----------------------------------------------------------------|
| Replacement of APU by airport ground equipment APU | aviation kerosene | [APU hourly fuel consumption (kg) × 1.47 - hourly power consumption of bridge-borne equipment (kW • h) × 0.12 kg / (kW • h)] × 10 - 3 × annual total number of using hours |
| Project Description | Energy Source | Formula |
|---------------------|---------------|---------|
| Construction of building energy monitoring system | Electricity/natural gas | Annual energy consumption of the original system - annual energy consumption of the renovated system – (energy conserved quantity by energy-saving lighting renovation + energy conserved quantity in heating/cooling renovation project + energy conserved quantity in heating/cooling new technology application project + energy conserved quantity in application of building new materials and new technology to energy conservation) |
| Renovation of energy-saving lighting | Electricity | Original lamp power \times original lamp number \times original lamp working time \times 365 - energy-saving lamp power \times energy-saving lamps number \times existing lamp working time \times 365 |
| Renovation of heating/cooling modification and pipe network laying | Electricity/natural gas/diesel | Original equipment power \times original running time - existing equipment power \times current running time |
| New technology application of heating/cooling | Electricity/natural gas/diesel | Original equipment power \times original running time - existing equipment power \times current running time |
| Optimization of power supply quality in airport area | Electricity | (Current system power factor reward (or fine) - original system power factor reward (or fine)) / electricity price of the project entity |
| Application of building new materials and new technology to energy conservation | Electricity/natural gas/diesel | (Original unit area energy consumption - current unit area energy consumption) \times current heating and cooling area – energy conserved quantity in heating/cooling renovation project + energy conserved quantity in heating/cooling new technology application project |
| Application of solar energy | Electricity/natural gas | Quantity of alternative traditional energy source |
| Purchase and transformation of new energy and energy-saving ground support vehicle | Diesel/gasoline | Annual average energy use of traditional energy-assurance vehicles - annual average energy use of existing vehicles |
| Energy Management System Construction Project | Electricity | Original energy use plan – systematically optimized energy use plan |
| Upgrade and improvement project of sewage treatment / water reuse facilities | Sewage | Annual reduction of sewage discharge + annual reduction of tap water consumption |
| Recovery of aircraft deicing fluid | Sewage | Annual recovery quantity of aircraft deicing fluid |

4. Data analysis
We surveyed 15 airports (groups) that were funded by special funds for energy conservation and emission reduction in civil aviation, and obtained relevant input and output data. Because the
numerical expressions were not uniform in the designed index system, we used the linear interpolation method to standardize the index values, and adopted the SE-DEA model to analyze the energy conservation and emission reduction efficiency of the sampled enterprises.

4.1 Analysis on efficiency values and scale returns
Max DEA 6.5 was utilized to evaluate the scale effectiveness, technical effectiveness and comprehensive effectiveness of energy conservation and emission reduction projects of various airport units. The calculation results in Table 2 show that 7 airport (group) units have achieved relatively DEA efficiency, with the efficiency values greater than or equal to 1. Among them, the efficiency value of ZGC1 is 355.105, indicating that the maximum input and output can be increased by 355.105 times in case of keeping its DEA relative efficiency. More than half of the airport units does not reach DEA efficiency, with the efficiency values less than 1. 7 ones of the 8 DEA-inefficient units have pure technical efficiency of less than 0.3 and scale efficiency whose mean value is less than the mean value of pure technical efficiency. As can be seen, the relatively low efficiency of energy-conservation and emission-reduction investments by various units is generally caused by the simultaneous low technical efficiency and low scale efficiency. Therefore, all units need to enhance the technology and the management technology level of energy conservation and emission reduction, improve the utilization efficiency of input resources, and expand output to increase the scale of output making its scale match the input and output.

4.2 Analysis on projection value and slack variable value
The projection values and slack variables of Table 2 show that, in order to improve the efficiency of energy conservation and emission reduction work, in the airport units that does not achieve DEA efficiency, ZB12 needs to reduce the input amount of energy in the adjustment plan of input indexes; For the adjustment plan of output indexes, all units that fail to meet the standard should increase the quantity of electricity conservation, while two units should increase other energy conserved quantity.

Table 2. Investment efficiency of energy conservation and emission reduction projects of China airport units.

| Airport code | crste | vreste | scale | Returns to scale | Increase of investment in energy conservation and emission reduction | Increase of energy input | Conserved quantity of aviation kerosene | Conserved quantity of diesel | Conserved quantity of electricity | Conserved quantity of water | Conserved quantity of other sources |
|--------------|-------|--------|-------|------------------|---------------------------------------------------------------|------------------------|-------------------------------------|-------------------------------|--------------------------------|-------------------------------|----------------------------------|
| ZGC1         | 355.105 | 1.000  | 1.000 | -                | 0.00                                                           | 0.00                   | 0.00                                 | 0.00                          | 0.00                           | 0.00                           | 0.00                             |
| ZBY2         | 102.680 | 1.000  | 1.000 | -                | 0.00                                                           | 0.00                   | 0.00                                 | 0.00                          | 0.00                           | 0.00                           | 0.00                             |
| ZHC3         | 19.951  | 1.000  | 1.000 | -                | 0.00                                                           | 0.00                   | 0.00                                 | 0.00                          | 0.00                           | 0.00                           | 0.00                             |
| ZHS4         | 11.221  | 1.000  | 1.000 | -                | 0.00                                                           | 0.00                   | 0.00                                 | 0.00                          | 0.00                           | 0.00                           | 0.00                             |
| ZGS5         | 9.326   | 1.000  | 1.000 | -                | 0.00                                                           | 0.00                   | 0.00                                 | 0.00                          | 0.00                           | 0.00                           | 0.00                             |
| ZBUL6        | 6.490   | 1.000  | 1.000 | -                | 0.00                                                           | 0.00                   | 0.00                                 | 0.00                          | 0.00                           | 0.00                           | 0.00                             |
| ZGS7         | 4.352   | 1.000  | 1.000 | -                | 0.00                                                           | 0.00                   | 0.00                                 | 0.00                          | 0.00                           | 0.00                           | 0.00                             |
| ZBM8         | 0.269   | 0.251  | 0.922 | irs              | 438.175                                                       | 0.00                   | 0.00                                 | 0.00                          | 17718428                       | 0.00                           | 0.00                             |
| ZGH9         | 0.244   | 0.986  | 0.213 | drs              | 0.00                                                           | 0.00                   | 0.00                                 | 1.043278                      | 0.02                           | 0.00                           | 0.00                             |
| ZG10         | 0.168   | 0.165  | 0.874 | irs              | 1196.426                                                      | 0.00                   | 0.00                                 | 6742423                       | 0.00                           | 0.00                           | 0.00                             |
| ZH11         | 0.092   | 0.139  | 0.569 | irs              | 492.719                                                       | 0.00                   | 0.20                                 | 10254702                      | 0.00                           | 0.00                           | 0.00                             |
| ZB12         | 0.068   | 0.180  | 0.325 | drs              | 1168.942                                                      | 348.21                 | 0.00                                 | 4.87                         | 0.00                           | 3684                          | 0.00                             |
| ZH13         | 0.022   | 0.123  | 0.150 | irs              | 442.590                                                       | 0.00                   | 0.00                                 | 16638218                      | 0.00                           | 0.00                           | 0.00                             |
| ZB14         | 0.020   | 0.070  | 0.242 | drs              | 6713.608                                                      | 0.77                   | 0.00                                 | 1.14                         | 0.00                           | 22.76                         | 0.00                             |
| ZG15         | 0.005   | 0.099  | 0.049 | irs              | 568.427                                                       | 0.00                   | 0.00                                 | 18738631                      | 0.00                           | 0.00                           | 0.00                             |
Note: “crste” means comprehensive efficiency, “vrste” means pure technical efficiency, “scale” means scale efficiency, “drs” means diminishing returns to scale, “irs” means increasing returns to scale, and “-” means constant returns.

5. Conclusions and suggestions

5.1 Expand project output scale, optimize resource allocation
The calculation results of investment efficiency showed that, most of the civil aviation energy conservation and emission reduction projects are relatively inefficient and of increased scale, with the slack variable of total investment of zero. This indicates that the output scale of energy conservation and emission reduction projects should be expanded in the future, such as optimizing the organization of project implementation, centralizing research and development of new technologies and new methods instead of decentralizing, reducing the overall fixed cost of civil aviation energy conservation and emission reduction projects, and further exerting the economies of scale in project investment. Meanwhile, the allocation of funds is supposed to optimize, focusing on and proactively funding the projects that have more outstanding effects on the energy conservation and emission reduction in civil aviation.

5.2 Strengthen technical research, strengthen the application of new methods
The pros and cons of technologies and methods affect the potential of green airport construction and development. In the planning, design and construction of China airports, it is necessary to continuously absorb new concepts such as green buildings, energy conservation buildings and sponge cities, to form new planning and design methods that are an integration of construction and operation, an integration of space planning, analogue simulation of runway configuration for flying area, noise and land compatibility planning, airport overall energy solution, and integrated pipe gallery design. The levels of green airports planning design and construction were improved with digitization technology, BIM technology, radiant air conditioning, stratified air conditioning, cold storage, ground source heat pump, photovoltaic power generation, frequency conversion control, light guide tube, automatic snowmelt and deicing, centralized collection and treatment of deicing fluid, and the new facilities of ground special air conditioning systems for aircrafts and clean-type ground service equipment.

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