

## RESEARCH ON EFFICIENCY-ORIENTED PORT GROUP INTEGRATION STRATEGY IN BOHAI RIM REGION

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**ABSTRACT.** *The Bohai Rim region has a large number of ports, and the larger ports include Tianjin Port, Qingdao Port, Dalian Port and Qinhuangdao Port, which is one of the five major port clusters in China. In the stage of localization of port management, local governments vigorously promote port construction, resulting in low-level repetitive construction, which leads to excess port capacity and hinders the transformation and upgrading of ports in the Bohai Rim region. In order to alleviate the vicious competition, the state advocates the integration of ports in the region into provincial administrative regions to form the pattern of “one province, one port”, for example, Hebei Port Group, Liaoning Port Group, and Shandong Port Group. However, there is administrative domination in port integration, and operational efficiency and capacity synergy are not fully considered, resulting in internal competition and reduced efficiency of the integrated ports. To address this phenomenon, this paper proposes an efficiency-oriented integration strategy for the Bohai Sea port group. The research results show that the efficiency-oriented integration of the Bohai Sea port group is more efficient than the current “one province, one port” integration strategy, which is an important reference value for the development of the next port development strategy in the Bohai Rim region.*

**Keywords:** Port integration, Bohai Rim port group, DEA (Data envelopment analysis) model

**1. Introduction.** At present, China is in the “14th Five-Year Plan” construction period, and the requirements for port development have been improved. General Secretary Xi Jinping pointed out that China is in an important development stage from a large port country to a strong port country, and the port industry should better serve the national development strategy [1]. The integration of port resources is the trend of port development in the new period.

The Bohai Rim region gathers a large number of ports, which is one of the five major port groups in China and plays an important role in regional economic development. However, while governments around the world promote the construction of ports, there are many problems that affect the development of ports. The Bohai Rim region is rich in shoreline resources, but there are excellent shorelines suitable for building deep-water berths that are not fully utilized in the construction process. At the same time, the Bohai Rim region involves a number of administrative entities. In the stage of port localization management, local ports are built independently without overall planning, resulting in no clear division of labor among ports, low-level repeated construction, and fierce vicious competition, which affect regional transformation and upgrading. The integration of port resources is conducive to the overall planning of the functions of the ports, promoting the

division of labor and cooperation among ports, avoiding internal conflicts. Integration has great significance to the transformation and upgrading of ports and the promotion of regional economic development. At the initiative of the government, the Bohai Rim region has formed the pattern of “one province, one port” with the provincial administrative unit as the unit, and Hebei, Liaoning and Shandong have all established their own port groups. However, the current integration is administration-led and does not fully consider the operational efficiency and the internal competition among integrated ports, resulting in the unreasonable allocation of port resources after integration, greater internal competition and the reduction of efficiency. To address this problem, this paper proposes an efficiency-oriented integration strategy for ports around Bohai Sea, and uses DEA method to evaluate the efficiency of ports before and after integration.

## 2. Problem Statement and Preliminaries.

**2.1. Port integration.** Port integration mainly refers to the process of port integration and layout adjustment between ports to build a competitive and cooperative pattern of ports with complementary advantages, clear division of labor and common development, so as to improve the competitiveness of ports in the region and promote the common development of ports in the region.

Huo et al. [2] analyzed the implementation of China’s port collaboration strategy, introduced the development history and mode of port integration in China, and pointed out that the trend of domestic port cooperation is to develop toward provincial port groups. After 2013, international port cooperation cases in China mainly occurred along the “Belt and Road Initiative” route. Wu and Yang [3] introduced the current “one port, one city” model of port governance in China, which has increased the motivation of port cities to develop local ports but also led to serious problems such as duplication of port projects. And the rationality and problems of the cooperative specialization approach proposed by the provincial government are analyzed from the perspective of system optimization. Liu and Dong [4] analyzed the overall situation of port resources in the Bohai Rim, pointed out the necessity of port integration in the Bohai Rim region and put forward the mode and requirements of integration. In the future, the ports in the Bohai Rim region will form three major centers of Tianjin-Hebei coastal port group, Liaoning coastal port group and Shandong coastal port group with Tianjin Port, Qingdao Port and Dalian Port as the core, respectively. Lu and Lu [5] put forward the countermeasures of Dalian Port to promote the integration of Liaoning ports, and Dalian Port, as the leading port group in Liaoning, should accelerate the pace of transformation and upgrading to play a leading role and promote the development and growth of Liaoning Port Group. Li [6] summarized the experience and practice of port integration in China and abroad, and based on the current situation of port development in Fujian, proposed to promote the reform of port integration in Fujian, as well as to promote the integrated development of Fujian-Taiwan ports and build a strait port cluster. Xu et al. [7] introduced the Shandong experience of provincial port integration, and Chen [8] sorted out the experience of Xiamen port integration, summarizing its strengths and weaknesses and providing effective reference for the benign development of domestic ports.

This paper’s primary academic contribution lies in utilizing the DEA model to examine port integration through the lens of efficiency. Previous research on port integration has primarily concentrated on integration models and experiences. This study broadens the scope of relevant literature and introduces a new approach to investigating port integration. Our research considers the difficulty of integration and integrates ports that are geographically close to each other in order to better achieve capacity synergy. At the same time, in order to make the resource allocation of Bohai Sea ports more effective, the positioning of each port is fully considered, homogeneity is avoided, and the integration is

based on the business type of the port, so that the integrated port is more comprehensive, based on the above considerations, the efficiency-oriented integration strategy of Bohai Sea port group is proposed.

**2.2. Port efficiency evaluation.** Port efficiency measurement is a common quantitative evaluation method to evaluate the effect of port integration, which provides strong support for the proposal and optimization of integration strategy. At present, the method commonly used by scholars is the non-parametric data envelopment analysis (DEA) method. Sun and Zhang [9] have reviewed the application and progress of various DEA models in port efficiency evaluation, among which most of the studies on port efficiency take “throughput” as output index and port facilities and equipment as input index. Cui et al. [10] divided 13 listed port enterprises into three regional port groups in North China, Central China and South China and conducted a comprehensive evaluation of logistics efficiency by DEA model. And based on the analysis results, recommendations were given for the allocation of port resources and the provision of operational efficiency. Mustafa et al. [11] used Charnes, Cooper, Rhodes’ DEA [12] (CCR-DEA) model and Banker, Charnes, Cooper’s DEA [13] (BCC-DEA) model to analyze the cross-sectional data of 15 container ports in each of South Central, Middle East and East Asia regions. Zhang [14] conducted an empirical study with the panel data of China’s top ten coastal ports logistics from 2012-2019. By constructing a reasonable evaluation index system, the port logistics efficiency is analyzed statically by using DEA method. Liu et al. [15] combined the DEA method with Malmquist index to measure the nine major ports in the Bohai Rim region and analyzed the overall efficiency of the major port groups and the efficiency of each port in the Bohai Rim region. Cao [16] and Gao et al. [17] used three-stage DEA model to study the efficiency of the main coastal ports along the “Belt and Road”. Zhu and Lin [18] used the three-stage DEA method to make an empirical study on the efficiency of ports in the Bohai Rim region. DEA method is applicable to the efficiency evaluation of multiple inputs and outputs, and is widely used and developed in port efficiency evaluation.

DEA method uses linear programming techniques to measure the efficiency scores of multiple decision variables. The DEA method can evaluate the efficiency of multiple inputs and multiple outputs without being affected by the input-output scale, and the weights are not influenced by human subjective factors, and it can also suggest improvement directions for non-efficient decision-making unit (DMU) based on its results. Therefore, DEA method is more suitable for the analysis of multi-input and multi-output ports than traditional methods such as regression analysis. In this paper, we use the input-oriented BCC-DEA model to analyze port groups from Bohai Rim region. These port groups are administration-oriented or efficiency-oriented.

The BCC-DEA model is applicable to the case of variable scale payoff, which divides technical efficiency into the product of pure technical efficiency and scale efficiency, making the analysis more accurate and relevant. Considering the actual situation of port operation, this paper selects the input-oriented BCC-DEA model for analysis and evaluation.

For any decision unit, the BCC-DEA model in pairwise form under input orientation can be expressed as

$$\min \theta - e(e^r S^- + e^r S^+) \tag{1}$$

$$\text{s.t.} \begin{cases} \sum_{i=1}^n X_j \lambda_j + S^- = \theta X_0 \\ \sum_{i=1}^n Y_j \lambda_j - S^+ = Y_0 \\ \lambda_j \geq 0, \quad S^-, S^+ \geq 0 \end{cases} \tag{2}$$

where  $j = 1, 2, \dots, n$  represents the decision unit, and  $X, Y$  represent input and output vectors, respectively. If  $\theta = 1, S^+ = S^- = 0$ , the decision unit is DEA effective, if  $\theta = 1, S^+ \neq 0$  or  $S^- \neq 0$ , the decision unit is weak DEA effective, and if  $\theta < 1$ , the decision unit is not DEA effective. The efficiency values calculated by the model are comprehensive technical efficiency (TE), which can be decomposed into scale efficiency (SE) and pure technical efficiency (PTE).

The BCC-DEA model is variable returns to scale. This leads to differences in the possible sets of production. The production set of port enterprises satisfies the assumptions of triviality, convexity, inefficiency and minimality, so the BCC-DEA model is effective to our research.

### 3. Empirical Analysis.

**3.1. Port integration in Bohai Rim region.** From the perspective of throughput, there are three major international shipping centers in the Bohai Rim region: Tianjin Port, Dalian Port and Qingdao Port. To achieve win-win cooperation, the three major centers should reasonably divide the work and compete in a staggered manner. The purpose of port resource integration is to optimize the efficiency of resource allocation, and the efficiency-oriented port integration strategy should avoid the internal competition among ports after integration. So, the type of port transportation business will be used as the basis of integration to make the allocation of port resources after integration more reasonable and reduce the vicious competition among ports as much as possible. To enhance the practicality of integrating other ports with the three central ports in the region, the geographical distance between them has been taken into account. Furthermore, in order to optimize the allocation of integrated port resources, the types of cargo transported by the ports have also been carefully considered to ensure a more rational allocation. Figure 1 shows the status quo of port integration in the Bohai Rim region and the integration strategies proposed in this paper. Tianjin and Hebei are actively promoting the Beijing-Tianjin-Hebei integrated development strategy, which seeks to deepen cooperation between these regions. As the regional economy continues to grow and trade increases, the cooperation between Tianjin and Hebei in the port sector is expected to become even more robust. So, we will consider Hebei and Tianjin ports together.

**3.2. Selection of indicators and data.** In this paper, Dalian Port, Yingkou Port, Jinzhou Port, Dandong Port, Panjin Port, Huludao Port, Qingdao Port, Yantai Port, Rizhao Port, Weihai Port, Weifang Port, Binzhou Port, Dongying Port, Tianjin Port, Tangshan Port, Qinhuangdao Port and Huanghua Port in the Bohai Rim are selected as the research samples. Considering variations in statistical standards across regions and years, and guided by data availability, this study employs the following input indicators: terminal length, number of berths, number of 10,000-ton berths, and output indicators of container and cargo throughput. The data of input and output indicators used are obtained from China Port Yearbook 2016-2020 and statistical yearbooks of various regions, and the insufficient data is supplemented by news reports.

**3.3. Analysis of DEA efficiency value.** Using DEAP2.1 software to bring the data into the established input-oriented BCC-DEA model, the values of port logistics efficiency in the Bohai Rim region are obtained as shown in Table 1.

1) Overall efficiency analysis. In general, the overall efficiency value of ports in each province has been growing steadily from 2015 to 2018, and generally declined in 2019, but it is still relatively effective. The scale value of the central integrated ports has been on the rise for five years except for Dalian integrated port which declined in 2019, among which Tianjin integrated port has been in DEA effective during five years. This indicates that the Bohai Rim regional port cluster has generally high resource utilization and is

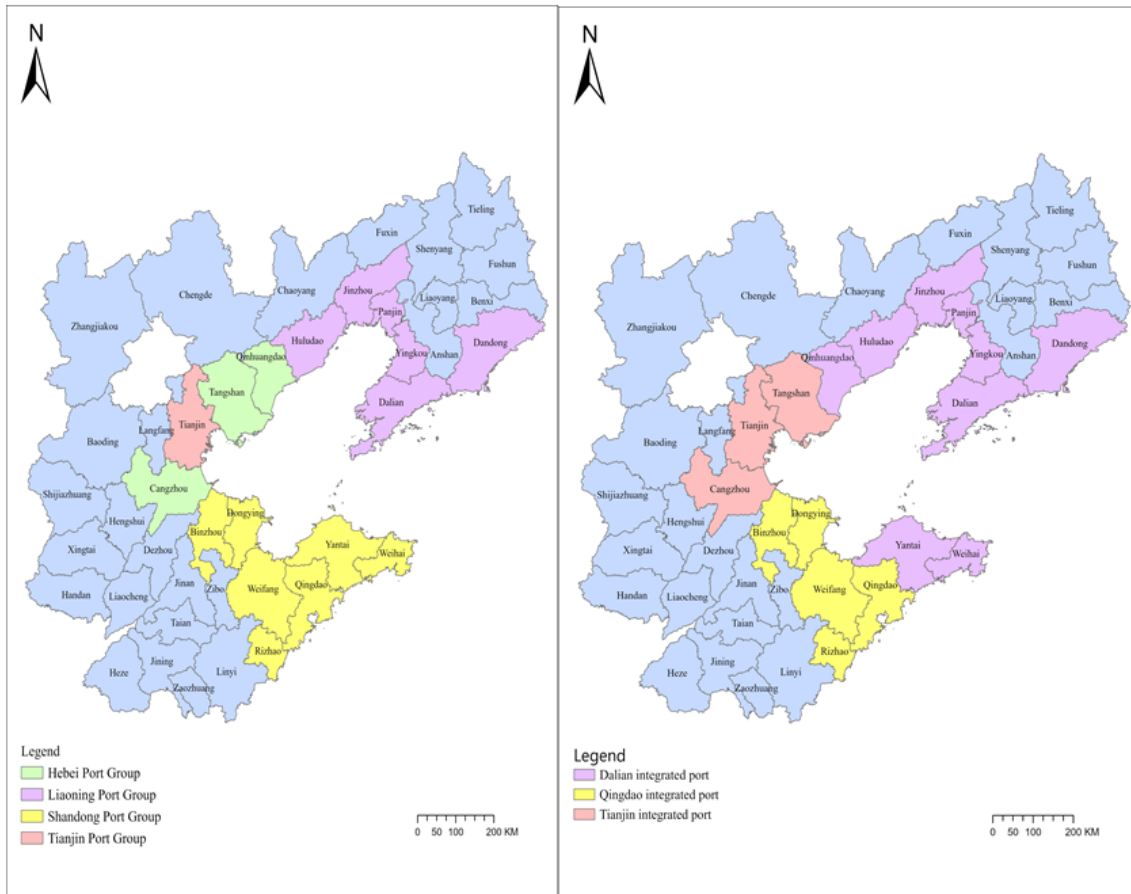


FIGURE 1. (color online) Different port strategies in the Bohai Rim region

in a relatively effective state regardless of the integration strategy. The fluctuation of pure technical efficiency value is small overall and is basically DEA effective. The pure technical efficiency value of each integrated port is lower than that of the provincial port group except for the Tianjin integrated port, which indicates that there is still room for improving the port integration under this strategy. From the scale efficiency value, the scale efficiency of the Bohai Rim regional port group has been increasing over the past five years, and the scale benefit of the integration strategy proposed in this paper is better than that of “one province, one port”. Comprehensive analysis shows that although the resource utilization of ports in the Bohai Rim region is at a high level, there is still room for improvement and the optimal state is not reached. Different ways of port resource integration have certain influence on the overall port operation efficiency in the Bohai Rim region, and reasonable resource integration is needed according to the actual situation of each port. The relatively low technical efficiency of ports in the Bohai Rim region indicates that the current impact on port efficiency is influenced by the technical management of port enterprises.

2) Comparative analysis of different integration strategies. From the average value of each efficiency in 2015-2019, except for scale efficiency, the port integration strategies proposed in this paper are slightly higher than those of provincial port groups. Specifically, the scale efficiency of Dalian integrated port is lower than that of Liaoning Port Group, indicating that after integrating a large number of ports for the port of Dalian, its port scale does not match the actual output and needs to be combined with the actual optimization of port scale. From the perspective of overall efficiency, the overall efficiency of Tianjin and Qingdao integrated ports is 1 under the efficiency-oriented integration strategy, which is in the best state of development. In terms of technical efficiency, the efficiency-oriented

TABLE 1. Port efficiency values in the Bohai Rim region

Port	2015			2016			2017		
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
Hebei	1	1	1	1	1	1	1	1	1
Shandong	0.914	1	0.914	0.992	1	0.992	0.842	1	0.842
Liaoning	0.765	0.879	0.870	0.846	0.913	0.926	0.848	0.891	0.951
Tianjin and Hebei	0.973	1	0.973	0.959	1	0.959	0.982	1	0.982
Mean	0.913	0.970	0.939	0.949	0.978	0.969	0.918	0.973	0.944
Integration of Tianjin	1	1	1	1	1	1	1	1	1
Integration of Dalian	0.753	1	0.753	0.824	1	0.824	0.758	1	0.758
Integration of Qingdao	1	1	1	1	1	1	1	1	1
Mean	0.918	1	0.918	0.941	1	0.941	0.919	1	0.919
Port	2018			2019			2015-2019 average		
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
Hebei	1	1	1	1	1	1	1	1	1
Shandong	0.846	1	0.846	0.833	1	0.833	0.902	1	0.885
Liaoning	0.753	0.779	0.967	0.631	0.632	0.998	0.801	0.819	0.942
Tianjin and Hebei	0.969	1	0.969	1	1	1	0.994	1	0.977
Mean	0.892	0.945	0.946	0.866	0.908	0.958	0.924	0.955	0.951
Integration of Tianjin	1	1	1	1	1	1	1	1	1
Integration of Dalian	0.671	1	0.671	0.618	0.691	0.895	0.775	0.938	0.780
Integration of Qingdao	1	1	1	1	1	1	1	1	1
Mean	0.890	1	0.890	0.873	0.897	0.965	0.925	0.979	0.927

integration strategy is more effective in terms of resource input and use. This is because the efficiency-oriented integration strategy is based on misaligned competition among ports, which can avoid vicious competition within ports to a certain extent and create greater output with a certain amount of input. On the whole, the efficiency-oriented integration strategy is better than the “one province, one port” integration strategy, and if the scale of ports can be optimized reasonably, it will better promote the high-quality development of regional ports.

**3.4. Main results.** The main results are summarized as follows.

1) From the perspective of comprehensive efficiency, the current resource utilization rate of the Bohai Rim Regional Port Group is relatively high. Although the pure technical efficiency is high, the use of technology and the operation and management are still the factors restricting the development of regional ports. In the past five years, the scale efficiency of the port group in the Bohai Rim region has been increasing.

2) The efficiency of the integration strategy proposed in this paper is higher than that of the current “one province, one port”. The comprehensive efficiency of the integrated ports in Tianjin and Qingdao is 1, which is in the best state of development, and the comprehensive efficiency of the integrated ports in Dalian is relatively low. On the whole, in addition to the scale efficiency, the average of the comprehensive efficiency and pure technical efficiency of the integration strategy proposed in this paper is higher.

#### 4. Conclusion and Suggestion.

**4.1. Conclusion.** The integration of port resources in the Bohai Rim region is a general trend, and this paper proposes an efficiency-oriented integration strategy of integrating other ports with three major centers in the region, and evaluates this integration strategy and the operational efficiency of provincial port groups by DEA method. The results show that regardless of the integration strategy, the overall development of ports in the

Bohai Rim region is better, and the comprehensive efficiency is improving until 2019. The efficiency-oriented integration of the Bohai Sea port group results in higher overall efficiency than the current “one province, one port” integration strategy.

From the regional perspective, the overall efficiency and pure technical efficiency of the efficiency-oriented consolidation strategy are slightly higher than that of the “one province, one port” consolidation strategy, while the scale efficiency is slightly lower. The reasons for this may be as follows: 1) the efficiency-oriented consolidation strategy takes account of the operational efficiency after consolidation and makes the resource allocation in the region more reasonable, so the comprehensive efficiency and pure technical efficiency of the consolidated ports are higher; 2) the scale of Tianjin-Hebei Port and Shandong Port Group under the “one province, one port” strategy is larger than that of Tianjin and Qingdao under the efficiency-oriented strategy. The efficiency-oriented strategy makes most of the ports integrated in Dalian, while the efficiency of Liaoning Port Group and efficiency-oriented Dalian integrated ports are low, making the scale efficiency of the whole region lower after the efficiency-oriented integration.

**4.2. Suggestion.** According to the research of this paper, the following suggestions for port integration in the Bohai Rim region are proposed: 1) break the administrative barriers and integration should be efficiency-oriented; 2) enhance cooperation and communication between ports and establish a resource sharing mechanism; 3) each port should improve its own development level while integrating.

In future research, it would be beneficial to enhance the index system, utilize more precise efficiency evaluation techniques to ensure the credibility of research findings, and explore alternative integration approaches to conduct further studies.

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## REFERENCES

- [1] M. Tong, Some major issues in the development of China’s ports in the 14th Five-Year Plan, *China Ports*, no.11, pp.6-10, 2019.
- [2] W. Huo, W. Zhang and P. S.-L. Chen, Recent development of Chinese port cooperation strategies, *Research in Transportation Business & Management*, vol.26, 2018.
- [3] S. Wu and Z. Yang, Analysis of the case of port co-operation and integration in Liaoning (China), *Research in Transportation Business & Management*, vol.26, 2018.
- [4] J. Liu and W. Dong, Analysis of port resource integration and development trend in the Bohai Rim region, *Marine Information*, no.1, pp.21-23, 2010.
- [5] B. Lu and H. Lu, Dalian port actively promote the integration of Liaoning port countermeasures, *Journal of Dalian Cadres*, vol.37, no.8, pp.60-64, 2021.
- [6] X. Li, Study on port integration practices at home and abroad and the development of port integration in Fujian, *Asia-Pacific Economy*, no.3, pp.122-128, DOI: 10.16407/j.cnki.1000-6052.2021.03.014, 2021.
- [7] F. Xu, X. N. Li and P. Zhuang, Shandong experience of provincial port integration, *China Water Transport*, no.10, pp.105-109, DOI: 10.13646/j.cnki.42-1395/u.2021.10.038, 2021.
- [8] Q. Chen, The experience of port integration development in Xiamen Port from the perspective of regional port integration, *Transportation Enterprise Management*, vol.36, no.2, pp.19-21, 2021.
- [9] S. Sun and P. Zhang, Research on port efficiency evaluation based on DEA method – A literature review, *Logistics Technology*, vol.38, no.12, pp.1-5+13, 2019.
- [10] Y. Cui, M. Hua and R. Li, Evaluation of logistics efficiency of listed coastal ports in China based on DEA model, *Logistics Technology*, vol.40, no.8, pp.61-68, 2021.

- [11] F. S. Mustafa, R. U. Khana and T. Mustafa, Technical efficiency comparison of container ports in Asian and Middle East region using DEA, *The Asian Journal of Shipping and Logistics*, vol.37, no.1, pp.12-19, 2021.
- [12] A. Charnes, W. W. Cooper and E. Rhodes, Measuring the efficiency of decision making units, *European Journal of Operational Research*, no.2, pp.429-444, 1978.
- [13] R. Banker, A. Charnes and W. Cooper, Models for estimation of technical and scale inefficiencies in data envelopment analysis, *Management Science*, vol.30, pp.1078-1092, 1984.
- [14] X. Zhang, Research on evaluation of port logistics efficiency based on DEA-Malmquist model, *Journal of Physics: Conference Series*, vol.1971, no.1, 2021.
- [15] T. Liu, G. X. Zhang and J. J. Huo, Analysis of spatial and temporal differences in technical efficiency of major ports in China's Bohai Rim region, *Technology Economics*, vol.32, no.8, pp.75-81, 2013.
- [16] G. Cao, Analysis of logistics efficiency of ports along China's "Maritime Silk Road" –based on three-stage DEA model, *Journal of Shandong Institute of Commerce and Industry*, vol.35, no.4, pp.96-104, 2021.
- [17] T. Gao, C. Liu and B. Yuan, Evaluation of efficiency of major coastal ports in China based on three-stage DEA model, *Journal of Shanghai Maritime University*, vol.41, no.3, pp.82-88, 2020.
- [18] B. Zhu and B. Lin, Efficiency evaluation of ports in Bohai Rim region based on three-stage DEA, *International Journal of Innovative Computing, Information and Control*, vol.17, no.3, pp.1067-1074, DOI: 10.24507/ijicic.17.03.1067, 2021.