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An Evaluation of Greenness of major Korean ports : A Fuzzy Set Approach

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Contents

Abstract

As environmental concerns over managing seaports are gaining its importance, evaluating the greenness of the port accordingly draws a serious academic and research attention. However, the lack of the research aptly dealing with this particular problem attributes to the complexity of the problems involving various quantitative and qualitative factors, combined with the appropriateness of an evaluation structure. Therefore, this paper attempts to make contribution to the literature (1) by identifying the factors and structure of analysis by making use a factor analysis (FA); (2) by utilizing experts' knowledge in solving the complex problems which are in nature ambiguous and unclear by adopting the fuzzy method; and (3) by ranking the targeted seaports and suggesting the pilot tail of methodology for evaluation of greenness of seaports. The results of the empirical research presented the rankings of Korean five trade ports for their greenness.

Key words : Seaports, Evaluation Structure, Fuzzy Methodology, Green Port, Factor Analysis (FA)

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I. Introduction

In an effort to spread the green issue of sustainable development in politics and economics all over the world the World Commission on Environment and Development (WCED) argued that a substantial part of environmental damage is caused by transportation industry.[1] Logistics coordinates all the activities involved in the movement of products through the supply chain at a minimum cost. Onto such a conventional definition of the logistics, green logistics explicitly takes into account environmental concerns which were previously treated as the external cost to the logistics in order to ease a burden on the environment while achieving economic rationality through an improvement of the transportation efficiency. That is, the activities of the green logistics imply building an efficient logistics system which can decrease environmental burdens inherent to the entire logistics environment, including management and disposal of the waste products. In this respect, promoting the green logistics can help businesses to improve their competitiveness by reducing distribution costs and also CO_2 emissions.

Many major seaports in the world have started their efforts for preserving the port environment. For instance, the Port of Tacoma in the US initiated its efforts of environment protection by extending the definition of environment to include people, businesses, culture and history of a place, in addition to its native species and natural system. Port environmental policies in Japan are noteworthy, compared with other countries. The Ministry of Transport Japan adopted a new policy such that a port becomes a pleasant and enjoyable space. This particularly policy is, in fact, an upgraded version of the previously passive environmental policy which focused merely on reducing negative effects of the usage and development of a port. The Port of Rotterdam in the Netherlands has ambitiously started promoting numerous economic activities widely within the port while simultaneously maintaining a clean port environment. *Green port construction is a long, comprehensive, systematic and complex task and is a matter concerning the overall situation and long-term strategic perspective*.[2] Thus, it is well known that in properly analyzing the greenness of a seaport needed are various quantitative and qualitative

1) Button and Henshe (2001).
2) He and Ji (2011).

factors as well as an adequate evaluation structure.

Nevertheless, previous research efforts are scant to aptly deal with these complex problems. Provided such a deficiency in the literature, this paper aims (1) to identify by using a factor analysis the evaluation structure and relevant factors; (2) to incorporate the expert's knowledge by adopting the Fuzzy method in solving the complex problems which are characteristically ambiguous, unclear, and vague; (3) to assess and rank targeted seaports while suggesting the pilot tail methodology as an adequate technique to evaluate the greenness of a seaport.

The remainder of this paper is structured as follows: Section 2 is devoted to a literature review concerning over port environmental management, improving eco-friendly port facilities, and reducing pollutions; In Section 3 such empirical analysis efforts are attempted as sampling, factor analysis (FA), and assessing the ports' greenness rankings by using the Fuzzy method. The final section concludes the paper with some policy implications.

II. Literature Review

In spite of the rising importance of the green port issue, literature on an eco-friendly port is generally insufficient. The majority of the researches conducted on this issue have dealt with the legislative and institutional aspects of the related laws.[3)] The importance of introducing the management of pollution sources in the seaport area was emphasized[4)] while the Self Diagnosis method could be used for checking up the environment conditions for the seaport.[5)] The efforts by the United Nations and other major countries for coping with the air and sea pollutions in the port area[6)] were introduced.

It attempted to measure the influence of international trade on the air pollutions in the US by making use of an economic costs estimation method.[7)] In studying on the water and sediment quality, benthic organisms, and pollution levels for Port Kembla in Australia for the 1975-1995 periods, the

3) Song and Han (2007).
4) Choi et al. (2000).
5) Park (2004).
6) Korea Maritime Institute (2005).
7) Gallagher et al. (2003).

pollution reduction practices had conducted by local heavy industries.[8] The significance, actualities and problems of constructing the green port in Tianjin China[9] were analyzed. They suggested for such measures to achieve the goal as applying the notion of green port construction in port planning, a rigorous environment impact assessment scheme, and establishment of Tianjin Port environment planning, strengthening environment management, and adopting various practical measures.

Unlike the majority of the previous studies that focused on merely suggesting one sided measures to enhance the eco-friendly management of seaports, comprehensive evaluation factors were provided.[10] In assessing the greenness of a seaport, they explicitly defined the evaluation variables. These variables include resources recycling within the port area, technical developments of the industries for the ocean waste disposal, development of the breakwater system for waterfront revitalization; dredging sand recycling, creation of the artificial sandbar and wetland, introduction of an environmental impact assessment, use of alternative fuels, introduction of a port environment management system, port facilities and equipments' improvement, incentives for the pollution reduction, use of renewable-energy sources, modal shift, construction methods for the noise reduction, and expansion of prevention facilities for the ocean pollution on the coastal region. However, they failed to indicate an appropriate methodology for evaluating the greenness of a seaport.

As mentioned before, however, evaluating the green port is a complex problem, and it involves various quantitative and qualitative factors. Furthermore, the expert knowledge should be adopted in calculating the qualitative factors because there are no secondary data available for them. In order to overcome such an inherent difficulty the Fuzzy method for investigating expert's evaluations[11] was applied. This method embraces the linguistic expression of expert's perceptions by utilizing the fuzzy number concept. In sum, the search results and the Fuzzy method can be nicely combined as an appropriate method for assessing the greenness of seaports.

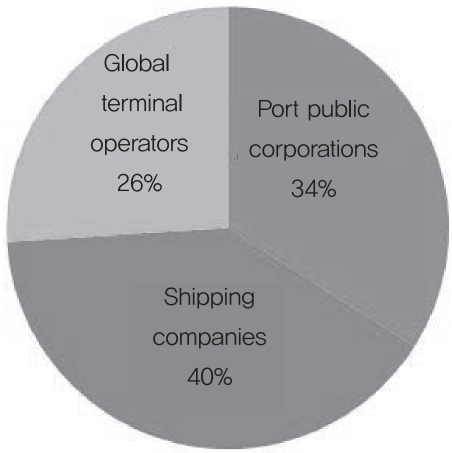
8) He and Morrison (2001).
9) He and Ji (2011).
10) Pak et al. (2009).
11) Yeo et al. (2011).

III. Empirical Analysis

1. Application of Factor Analysis

In this paper the Factor Analysis of SPSS was adopted to examine the factors that influence on selecting green port criteria. Factor analysis reduces attributes from a larger number of variables to a smaller number of factors by collecting similar items. It is possible to find the underlying latent variables that are reflected in the observed variables. Among many different methods for the factor this paper relied for the data reduction of these factors on the surveys of experts who are engaged in port public corporations, shipping companies and global terminal operators. The questionnaire was distributed to the stakeholders of related seaport from August 24 to September 21, 2009. The 75 respondents were answered out of 100. The distribution ratio of survey is shown in Figure1.

<Figure 1> Distribution ratio of survey



The Factor Analysis was conducted based on the criteria suggested in the previous research, and five representative factors were drawn out as listed as in Table 1. These five extracted factors from 15 factors could be used for evaluating the rankings of targeted ports using the Fuzzy method. All component loadings were over 0.5 in the rotated component matrix using the Varimax rotation. It was regarded as identical factors when component loading being over 0.5.

<Table 1> Rotated Component Matrix

	Components				
	1	2	3	4	5
Use of alternative fuels	.742	.129	-.082	.051	-.084
Incentives of pollution reduction	.725	-.005	-.276	.365	.119
Renewable-energy using	.644	.244	.057	-.090	.384
Dredging sand recycling	.553	.090	.425	.026	.093
Port facilities and equipment improvement	.168	.796	-.109	.065	-.072
Development of breakwater system for waterfront revitalization	.041	.673	.305	.027	.116
Construction methods of noise reduction	.283	.521	.229	.178	.237
Technical developments on the industries of the ocean waste disposal	-.150	.158	.818	.014	-.063
Resources recycling within a port area	.040	.030	.795	.262	.028
Introduction of port environment management system	-.011	.474	-.151	.670	-.100
Expansion of prevention facilities of ocean pollution	.042	.189	.306	.657	-.005
Efficient construction plans	.240	-.172	.248	.651	.152
Modal shift	.134	-.055	-.074	-.062	.844
Introduction of environmental impact assessment	.008	.071	-.044	.519	.572
Creation of artificial sandbar and wetland	.043	.459	.168	.128	.565

From the Factor Analysis results, as shown in Table 1, the five representative factors were labeled as: (1) ease the environmental burden; (2) environment-friendly method and technology development of construction; (3) utilization of resources and waste inside a port; (4) efficient planning and management of port operation; and (5) port redevelopment with introduction of waterfront concept.

2. Fuzzy Method

1) Fuzzy Set

The fuzzy set theory which accepts linguistic ambiguity was first introduced by Zadeh as a widening of the classical concept of a set.[12)] The fuzzy theory has distinctively specific features, in comparison with existing theories as shown in Table 2.

12) Zadeh (1965).

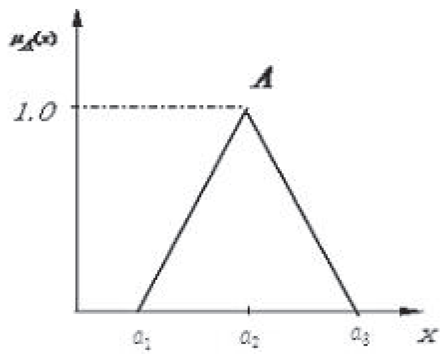
<Table 2> Comparisons with existing science and Fuzzy theory

Classification	Existing science	Fuzzy theory
Viewpoint	Objectivity	Admitting subjectivity
Data	Accuracy	Admitting incompleteness, ambiguity
Theory	Mathematical, theoretical rigidity	Not necessary to be precise
Measurement	Quantitative	Possibility of qualitative interpretation
Interference	Eliminate within the limits of the possible	Admitting somewhat
Experience	Eliminate within the limits of the possible	Use possibility

Source: Kim (2008)

Fuzzy sets are the sets that have degrees of membership of elements. The membership of elements in a classical set is assessed in binary terms according to bivalent condition an element either belonging or not belonging to the set. Conversely, the Fuzzy set theory is allowed to the gradual assessment of the membership of elements in the set. This is told with the aid of a membership function valued in the real unit interval [0, 1] (Fig.2). Fuzzy sets generalize classical sets because the indicator functions of the classical sets are special cases of the membership functions of the fuzzy sets, if the latter only have values 0 or 1. Classical bivalent sets are in the fuzzy set theory commonly called crisp sets. Triangle fuzzy number $\bar{A}$ consists of three parameters (a1, a2, a3), and the membership function of $\bar{A}$ can be denoted $\mu A(x)$ as shown in Equation 1.

<Figure 2> Function of Triangle Fuzzy Number



$$\mu A(\chi) = \begin{cases} 0, & \chi \prec a_1 \\ \dfrac{\chi - a_1}{a_{2} - a_3}, & a_1 \le \chi \le a_2 \\ \dfrac{a_3 - \chi}{a_3 - a_2}, & a_2 \le \chi \le a_3 \\ 0, & \chi \succ a_3 \end{cases} \tag{1}$$

I[th] triangle fuzzy number among the membership function 'n' is defined as in Equation 2.

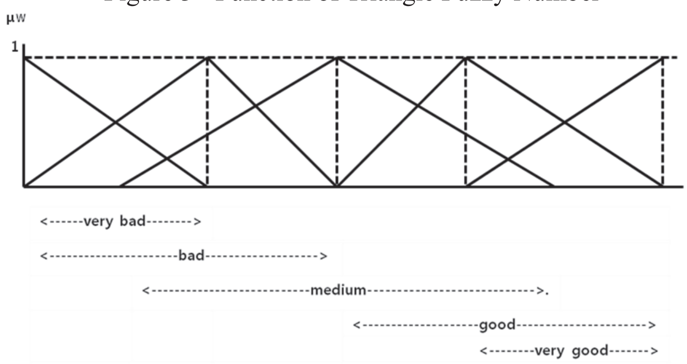
$$\bar{A} = (a_1^{(i)}, a_2^{(i)}, a_3^{(i)}, \quad i = 1, 2, 3 \cdots\cdots, n \tag{2}$$

And, fuzzification $\bar{A}$ is defined as follow:

$$\bar{A} = A_{ave} = \frac{\overline{A_1} + \overline{A_2} + \cdots + \overline{A_n}}{n} = \frac{(\sum_{i=1}^{n} a_1^{(i)}, \sum_{i=1}^{n} a_2^{(i)}, \sum_{i=1}^{n} a_3^{(i)}}{n} = (a_1, a_2, a_3) \tag{3}$$

The linguistic variables which were measured as the form of word or sentence can be quantified using the Fuzzy method. The linguistic term is able to denote a fuzzy set. Figure 3 shows a triangle membership function which values the linguistic measures such as very bad, bad, medium, good and very good. The value of the triangular membership function is defined as shown in Table 3.

<Figure 3> Function of Triangle Fuzzy Number



Source : Herrera et al. (2000)

<Table 3> Value of Triangle Membership function

Very Bad(VB)	(0, 0, 0.3)
Bad(B)	(0, 0.3,0.5)
Medium(M)	(0.2,0.5,0.8)
Good(G)	(0.5,0.7,1)
Very Good(VG)	(0.7, 1, 1)

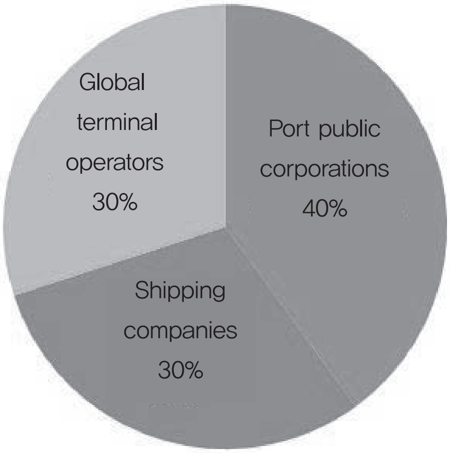
The final step of the Fuzzy method is defuzzification. The aim of defuzzification is to convert the entire results of the fuzzy set obtained in the previous step into actual numbers. The most common defuzzification method is Center of Gravity. This method resolves the center of the area of the combined membership functions.

$$y^{*} = \frac{\sum \mu\,(yi)xi}{\sum \mu \quad \mathrm{yi}} \tag{4}$$

2) Application of Fuzzy Set

The Fuzzy method is chosen for evaluating green ports on the ground that it contains the characteristics of complexity and ambiguity. Actually, it is not easy to evaluate its qualitative factors of the green criteria for seaports. Collecting the quantitative data about qualitative factors is limited. For all the reasons given previously, this study is evaluating the ports by fuzzifying the result from experts' survey. Especially, in the light of port evaluation, it is very difficult to determine the ranking with simple quantitative data given the paucity of material on specific port's quantitative datum. Experts' survey is a proper consideration by evaluating port's a certain degree of greening. Because evaluating green ports is difficult to express in numbers the ambiguous linguistic variables that are presented the green port criteria. The survey was conducted from October 05, 2009 to October 10, 2009. The 39 out of 40 respondents from port public corporations, shipping companies and global terminal operators were replied. The distribution ratio of survey is shown in Figure4.

<Figure 4> Distribution ratio of survey

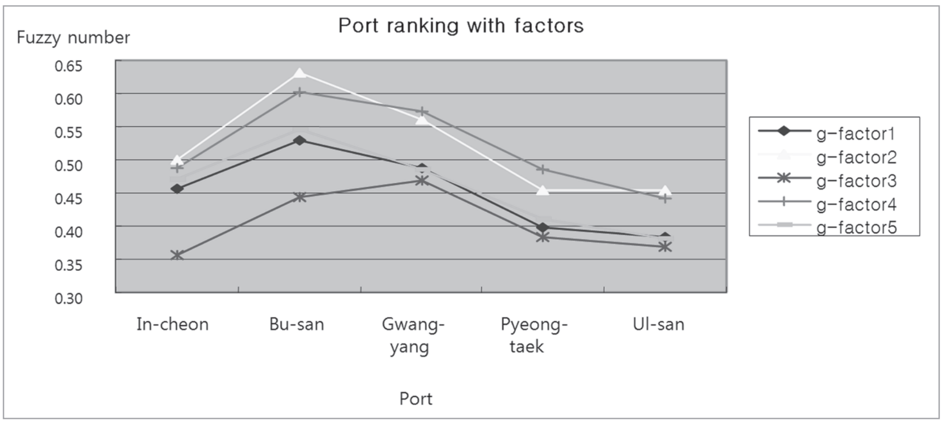


The results of fuzzy method based on experts' survey are shown in Table 4 and Figure 5.

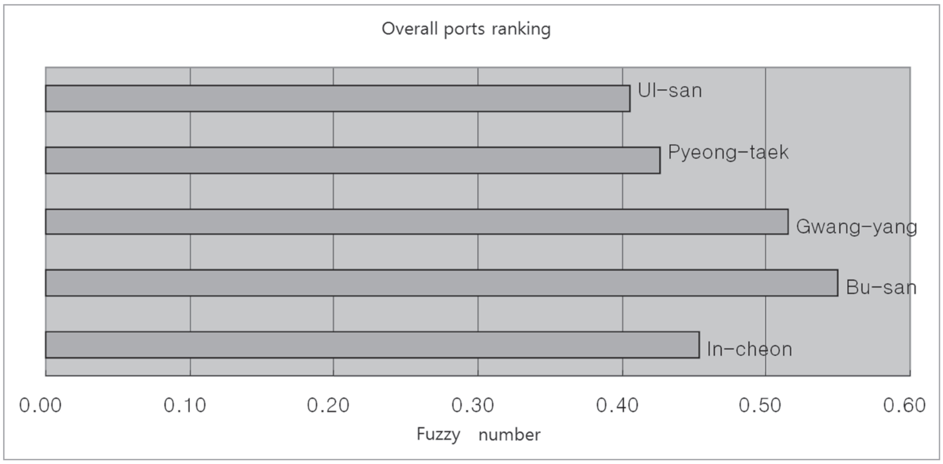
<Table 4> Port ranking on each factor

	G-factor(Ranking)				
	In-cheon	Bu-san	Gwang-yang	Pyeong-taek	Ul-san
Factor 1	0.457(3)	0.528(1)	0.487(2)	0.398(5)	0.383(6)
Factor 2	0.500(3)	0.631(1)	0.560(2)	0.455(4)	0.455(4)
Factor 3	0.357(3)	0.444(2)	0.469(1)	0.383(5)	0.368(4)
Factor 4	0.487(3)	0.601(1)	0.573(2)	0.485(4)	0.442(5)
Factor 5	0.454(3)	0.550(1)	0.509(2)	0.426(4)	0.406(5)
Overall Ranking	3	1	2	4	5

<Figure 5> Ports ranking on each factor



<Figure 6> Overall port ranking



In terms of the factor 1 representing ‘ease the environmental burden’ Bu-san and Gwang-yang took the first and second positions in the ranking, respectively. Regarding the factor 2 (environment-friendly method and technology development of construction), Bu-san ranked first while Gwang-yang is at the back of Bu-san. Bu-san has changed the diesel fuel which was a power source of RTGC into electricity. Subsequently, 202 tons per year in nitrogen compound, 9 tons in diesel dust, and 18.2 billion won in the operating expense have decreased, to which it may be attributed for being selected as the first ranker in the factors 1 and 2.

The third factor represents the utilization of resources and waste within the port area. Gwang-yang ranked the first for this factor. Marine waste affects the marine ecology because it is a highly resistant refractory and buoyant in the water property. Usually, 70-80% of marine waste originates from the land, while the remaining 20-30% comes from the sea. Therefore, it is a very important factor to conserve the marine ecosystem and also to reduce waste collection costs. Gwang-yang achieved a high mark in this factor, ranking the first. Bu-san took the first position again for the results of defuzzification by experts’ survey about the factor 4 (efficient planning and management of port operation). An efficient planning and management of the port operation is the skill to minimize air pollutant emissions generated from the port operation. It is connected to the operation method of enhancing the productivity and efficiency of stuffing and stripping. Stuffing and stripping are divided into the five systems of ships: docking system, berth system, yard system, transfer system and gate system. These systems correspond to the sub-phrase of port operation composed of different load and unload stages. It seems that Bu-san earned the highest mark in this operating field for the reasons mentioned above.

Lastly, the factor 5 stands for port redevelopment with the introduction of waterfront concept. Overall, Bu-san is the best port and Gwang-yang is the second best port in the green port rankings, as shown in Figure 6.

IV. Conclusion

The importance of the environmental concerns in managing the seaports is being emphasized. Many major seaports around the world have made started their efforts for suitable development as a green port. Evaluating the green of a port is worthy of academic and research attention. A series of meaningful results were derived from the adaptation of the methodology suggested, producing for port related stakeholders some useful insights into the concept of a green port.

The Green Criteria of a seaport (GCS) were successfully identified using a Factor Analysis (FA) to evaluate the eco-friendly level of the seaport. These are Factor 1: 'ease the environmental burden', Factor 2: 'environment-friendly method and technology development of construction', Factor 3: 'utilization of resources and wastes within a port area', Factor 4: 'efficient planning and management of port operation' and Factor 5: 'port redevelopment with introduction of waterfront concept'. In addition, this paper showed the rankings of Korean five trade ports i.e. In-cheon, Bu-san, Gwang-yang, Pyeong-taek and Ul-san using the GCS suggested. The fuzzy method was used to evaluate the greenness of seaport because the green port analysis is characteristically complex and ambiguous.

The results showed that Bu-san took the first positions in the Factor 1: ease the environmental burden, the Factor 2: environment-friendly method and technology development of construction, the Factor 4: efficient planning and management of port operation, and the Factor 5: port redevelopment with the introduction of waterfront concept. Gwang-yang ranked the first on the Factor 3: utilization of resources and waste inside the port. Overall, Bu-san was chosen the best port as far as the greenness of seaports is concerned in Korea. The fuzzy method suggested in this research can also be adapted to logistics related industries, e.g., the evaluation of competition between air ports, and that of transport mode and distribution centre selection and competition. In this respect, further studies will be needed.*

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