The Impact of the Sewol Ferry Tragedy on the Coastal Ferry Industry Efficiency: A Case of South Korea

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Abstract--- Whereas an abundance of islands dominate the coastline of South Korea, the area's maritime transportation has its success depend on an efficient coastal ferry industry. Indeed, ferry disaster pose severe impacts on an industry's operational efficiency. In this study, the main aim was to gain insight into the coastal ferry industry of South Korea, especially regarding its operational efficiency. The study strived to gain insights into this parameter by investigating the situation before and after MV Sewol sank off the South Korean coast. To analyze time-series from 2007 to 2016, the study employed slacks-based measure (SBM)-DEA and data envelopment analysis (DEA). From the findings, the study established that based on the Regional Office of Oceans and Fisheries (ROOFs), the industry's total efficiency in South Korea's respective provinces decreased. Indeed, considerable decline was noted in Pohang, Mokpo, Jeju, and Incheon. In 016, the most inefficient region was Busan. The implication for government authorities and companies is that the study increased the understanding about the extent to which ferry disasters could affect industry operational efficiency. In future, it becomes essential for the affected countries and companies to establish relevant strategies through which the coastal ferry industry could be improved, with South Korea unexceptional.

Keywords--- Ferry Tragedy, Study Employed DEA, DMUs, SBM-DEA.

I. INTRODUCTION

ONE of the worst maritime disasters in South Korea is the sinking of the Sewol ferry. The disaster occurred on 16 April, 2014. For months, the disaster paralyzed society in South Korea. Up to date, the impact of the disaster remains palpable [1]. Imperatively, coastal ferries support maritime tourism and also enable island residents to connect to the mainland [2]. For studies that have analyzed ferry disasters, the majority have addressed the subject of how the catastrophes affect the victims' mental health [3-5]. The eventuality is that the extent to which accidents and disasters affect coastal ferry operations is yet to receive in-depth analysis [6, 7].

In this study, the main aim was to evaluate how ferry disasters affect the coastal ferry industry's operational efficiency, with specific insights gained from the context of South Korea – in relation to the Sewol ferry tragedy. Indeed, the study's insights arose from time series data documented before and after 2014. As such, the period of analysis ranged from 2007 to 2016. Given that the study focused on a subject over time, efficiency trends were measured using DEA-window analyses. Also, the parameter of operational efficiency in relation to the ferry disaster was analyzed using SBM-DEA.

The rest of the paper is organized in such a way that the section that follows describes the methodology that was employed, followed by a discussion of how ferry disasters alter the operational efficiency of the ferry industry (with a case analysis of South Korea on the focus), eventually culminating into the conclusion and implications.

II. METHODOLOGY

This study employed DEA. Indeed, DEA constitutes a quantitative method that aids in measuring the given decision-making units' efficiency [7-10]. In particular, DEA examines various outputs and inputs of a given firm [9]. Through DEA-window analysis, this study strived to offer a dynamic evaluation of the coastal ferries' operational efficiency.

From the previous literature, the use of SBM-DEA is informed by the need to counter limits with which radial measures of efficiency are associated [3, 10]. Imperative to note is that DEA-window analysis is applied to time-series data and relies on the aspect of moving averages, upon which

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efficiency trends are detected in the target decision-making units – over time [5]. It is also notable that when DEA-window analysis is employed, the respective DMUs in the target period are treated independently.

In so doing, the individual values obtained for each DMU are compared to those obtained for other DMUs in the same period [7].

In so doing, the efficiency of the DMUs is analyzed relative to their performance over the respective periods of time. To calculate the efficiency values, this study utilized the equation:

$$X_{kt} = \begin{bmatrix} x_1^k & x_2^k & \cdots & x_N^k \\ x_1^{k+1} & x_2^{k+1} & & x_N^{k+1} \\ \vdots & \vdots & \ddots & \vdots \\ x_1^{k+l} & x_2^{k+l} & \cdots & x_N^{k+l} \end{bmatrix}, \quad Y_{kt} = \begin{bmatrix} y_1^k & y_2^k & \cdots & y_N^k \\ y_1^{k+1} & y_2^{k+1} & & y_N^{k+1} \\ \vdots & \vdots & \ddots & \vdots \\ y_1^{k+l} & y_2^{k+l} & \cdots & y_N^{k+l} \end{bmatrix}$$

Regarding the case of SBM-DEA analysis, previous studies affirm that this approach is a powerful non-radial technique through which more comprehensive efficiency analyses could be obtained [6-9]. Hence, this study applied SBM-DEA to determine industry operational efficiency. With slacks considered, the specific SBM-DEA model that this study employed was in the form:

$$\text{Min } \rho = \left(\frac{1}{m}\sum_{i=1}^{m}\frac{x_{ik} - s_i - s_i^-}{x_{ik}}\right)\left(\frac{1}{s}\sum_{r=1}^{s}\frac{y_{rk} + s_r^+}{y_{rk}}\right)^{-1}$$

The SBM-DEA framework above was subject to the conditions:

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{ik} \qquad (i = 1, \ldots, m)$$

$$\sum_{j=1}^{n} y_{rj}\,\lambda_j - s_r^+ = y_{ik} \qquad (r = 1, \ldots, s)$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad (j = 1, \ldots, n)$$

$$s_i^- \geq 0, s_r^+ \geq 0, \lambda_j \geq 0$$

III. Results

With a case study approach employed, the coastal ferry industry's operational efficiency was evaluated. In South Korea's respective provinces, the research setting involved the industry run by 10 Offices of Oceans and Fisheries (ROOFs).

The data that was utilized involved a ten-year costal ferry data ranging from the year 2007 to 2016. The main input variables involved the number of routes (X3), the actual vessels that sailed (X2), and the number of vessels (X1). On the other hand, the study's central output variable involved the number of passengers (Y). The table below shows the findings for the period ranging from 2007 to 2016.

Table 1 - A Summary of the Output and Input Variables

Input and Output Variables

ROOFs	Year	Number of vessels	Number of actual vessels sailing	Number of routes	Number of passengers (unit: persons)
Gunsan	2007	13	13,264	2	318,688
	2008	10	7,818	2	325,867
	2009	9	6,931	3	291,130
	2010	8	7,785	5	267,940
	2011	7	7,180	2	258,507
	2012	7	6,466	2	247,644
	2013	8	6,800	2	279,934
	2014	6	7,030	2	226,074
	2015	4	1,335	3	138,053
	2016	5	5,545	2	217,989
Daesan	2007	7	6,450	3	287,725
	2008	7	5,840	4	258,138
	2009	6	5,686	4	353,803
	2010	5	5,548	6	274,279
	2011	9	8,536	5	399,453
	2012	7	7,972	4	353,772
	2013	8	8,536	5	382,940
	2014	7	8,109	4	328,306
	2015	8	4,456	3	355,050
	2016	7	7,194	2	327,495
Donghae	2007	3	944	2	256,719
	2008	2	979	2	310,183
	2009	2	1,001	2	338,452
	2010	3	1,007	2	316,943
	2011	3	1,606	4	501,643
	2012	6	1,526	6	559,687
	2013	5	1,537	5	589,762
	2014	6	997	5	350,046
	2015	9	7,104	5	232,063
	2016	6	1,230	1	393,592
Masan	2007	22	45,146	10	2,214,265
	2008	24	45,344	10	2,543,454
	2009	29	47,489	12	2,673,306
	2010	26	46,928	15	2,516,528
	2011	26	36,643	10	1,709,151
	2012	21	33,299	9	1,646,140
	2013	20	33,473	8	1,931,683
	2014	20	31,105	8	1,708,820
	2015	21	11,529	4	690,905
	2016	28	33,775	8	1,765,866
Mokpo	2007	63	127,340	26	2,394,184
	2008	71	136,671	23	2,983,093
	2009	57	141,563	22	3,491,103
	2010	60	132,884	35	3,549,643
	2011	66	125,100	22	4,106,729
	2012	63	123,534	21	3,845,342
	2013	60	138,169	21	4,643,233
	2014	63	137,168	21	4,051,346
	2015	73	117,877	31	3,775,184
	2016	68	141,049	30	4,261,417
Busan	2007	11	13,663	6	941,856
	2008	11	12,147	6	1,011,812
	2009	13	11,871	6	911,354
	2010	11	10,825	6	761,811
	2011	10	1,533	6	146,261
	2012	2	440	2	41,057
	2013	3	732	2	107,695
	2014	3	663	2	89,891
	2015	3	3,313	1	3,433
	2016	5	236	2	25,392

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Yeosu	2007	25	25,177	12	713,078
	2008	22	24,329	13	751,156
	2009	28	25,832	13	773,021
	2011	24	29,660	12	877,973
	2012	32	33,504	17	1,261,736
	2013	25	35,030	13	1,368,683
	2014	28	34,617	13	1,179,789
	2015	35	41,512	16	2,425,098
	2016	25	31,334	14	1,558,056
Incheon	2007	22	14,979	10	898,846
	2008	19	13,721	9	992,732
	2009	17	12,506	9	1,011,615
	2010	16	12,603	12	1,024,222
	2011	14	13,141	10	1,109,566
	2012	21	13,895	11	1,246,923
	2013	42	48,276	10	2,681,351
	2014	18	12,068	11	1,026,160
	2015	17	16,926	12	610,690
	2016	13	12,148	11	933,840
Jeju	2007	9	6,454	4	499,799
	2008	7	7,207	5	698,366
	2009	6	7,212	4	783,004
	2010	7	8,257	4	887,730
	2011	8	9,314	4	1,017,919
	2012	7	9,610	4	1,171,804
	2013	7	10,125	4	1,230,710
	2014	10	10,805	5	1,182,335
	2015	14	9,622	8	357,825
	2016	9	11,045	4	1,553,926
Pohang	2007	4	958	2	290,881
	2008	5	924	2	357,902
	2009	4	795	2	336,372
	2010	4	636	2	262,532
	2011	6	974	5	375,879
	2012	4	876	3	397,624
	2013	6	1,287	3	488,293
	2014	6	870	4	309,872
	2015	7	2,637	6	54,059
	2016	10	1,485	10	475,397

Also, averages were done for three periods. Whereas the period from 2011 to 2013 had its average stand at 0.607, there was a significant decline after the Sewol accident, with the period from 2014 to 2016 recording an average of 0.468. With Yeosu and Daesan exceptional, the rest of the ROOFs experienced a decrease in the efficiency. The case of Incheon witnessed a decline from 0.638 to 0.416 while the efficiency for Jeju declined sharply, dropping from 0.949 to 0.657. A major factor that explained this trend involved the decision to shut down the Incheon-Jeju route. Notably, it was this route that MV Sewol was operating. Similar declines in Efficiency were observed for the remainder of the DMUs. An example is a case where there was a significant drop for Mokpo, decreasing from 0.640 to 0.391. During the same period, a drop from 0.950 to 0.655 was recorded for the case of Pohang. The figure below summarizes these findings.

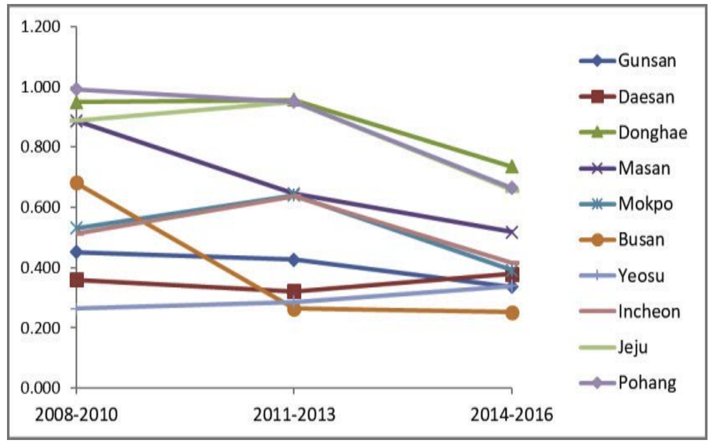

Figure 1 - A Summary of Trends in DMU Efficiency

When the parameter of actual vessels sailing was analyzed, the largest slack amount was found to be experienced by Mokpo. Some of the factors that accounted for this trend included failures of ships and sailing suspensions due to inspections or foul weather conditions. In relation to the number of routes, the study established that Incheon and Busan ports required the most upgrading. The required improvements for these ports stood at 60% and 90.41% respectively. Another variable that was investigated constituted the number of passengers. Notably, the latter attributed reflected the study's output variable. From the specific results that were obtained, the most improvement was required at Busan and Gunsan, standing at 197.41% and 256.42% respectively.

IV. Conclusion and Future Implications

In summary, one of the efficient transportation modes entails coastal ferries, especially from the economic, social, and environmental perspectives. The trend is more pronounced in situations involving countries with numerous islands, as they experience the movement of cargo, tourists, and residents to and from the mainland. However, situations that come with ferry disasters cause severe losses or assets and human lives, hence diminishing the coastal ferries' operational efficiency. This case study strived to determine how ferry disasters affect the coastal ferries' operational efficiency, with SBM-DEA and DEA-window analyses utilized. Also, the study targeted the period from 2007 to 2016 and gained specific insights from time-series data. The role of applying DEA-window analysis was to establish trends in operational efficiency. On the other hand, the use of SBM-DEA strived to measure the output and input slacks. The role of these analyses was to give more comprehensive outcomes. From the findings, this study established that the period stretching from 2014 to 2016, which came after MV Sewol disaster, experienced a decline in the overall efficiency. When specific institutions or zones were analyzed, the most significant decrease was experienced by Pohang, Mokpo, Jeju, and Incheon. Additional insights that were gained after applying SBM-DEA analysis demonstrated that the least efficient zone was Busan, results that were found for the year 2016.

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Indeed, the study's results exhibit implications from industrial and academic viewpoints. Particularly, the study sensitizes audiences regarding the relationship between ferry disasters and the coastal ferry industry's operational efficiency. In future, it is recommended that scholarly investigations examine some of the strategies that the coastal ferry industry could implement to respond to ferry disasters and restore operational efficiency.

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