The Promotion of Environmental Management in the South Korean Health Sector—Case Study

Jong-Ryool Kim 1, Eui-Chan Jeon 2, Seongmoon Cho 3 and Hana Kim 4,*

1 Ministry of Environment, Sejong City 30103, Korea; jrkim124@msn.com
2 Department of Environment & Energy, Sejong University, Seoul 05006, Korea; ejeon@sejong.ac.kr
3 Korea Environmental Industry & Technology Institute, Seoul 03367, Korea; smcho@keiti.re.kr
4 Corporate Course for Climate Change, Sejong University, 209, Neungdong-ro, Gwangjin-gu, Seoul 05006, Korea
* Correspondence: hanakim0729@sejong.ac.kr

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Abstract: Because of the comprehensiveness and urgency of environmental challenges, every stakeholder needs to be engaged in reducing environmental impacts. The healthcare sector has rarely been studied, despite its intense effects on the environment, particularly through generating various forms of hazardous waste and intensively consuming energy and water. Many healthcare facilities exist in South Korea, and every citizen frequently visits hospitals thanks to the convenient system. To reduce the environmental impacts of the healthcare sector, the South Korean government has implemented various policy measures aimed at promoting environmental management in that sector. This study evaluated the eco-efficiencies of 21 hospitals from 2012 to 2015 using data envelopment assessment (DEA), used the analytical hierarchy process (AHP) to analyze hospital staff members’ answers to a questionnaire asking about the relative importance and performance of individual environmental management tasks, and also identified environmental management tasks that should be prioritized by building an importance-performance analysis (IPA) matrix using those questionnaire responses. This study found that eco-efficiencies have improved during the period, and that mandatory policy measures were more effective than voluntary agreements for improving eco-efficiency. This implies that rigorous reporting and monitoring should be implemented along with any voluntary agreement. In addition, this study found that the top priorities are “establishment of vision and strategy for environmental management” and “organization of task team for environmental management and task assignment”. This shows the necessity of additional policy measures, such as training or consulting to promote the priorities. In addition to policy recommendations for diffusing environmental management in the South Korean healthcare sector, the methodological approach sheds light for researchers interested in environmental management in the healthcare sector because previous studies depended on qualitative approaches, particularly case studies.

Keywords: environmental management; eco-efficiency; healthcare sector; data envelopment assessment; importance-performance analysis

1. Introduction

The 2015 Decision of the Conference of Parties (COP) in Paris emphasizes the participation of non-Party stakeholders, including cities and other subnational authorities. In addition, the decision encourages Parties to cooperate closely with non-Party stakeholders in an effort to strengthen and expand mitigation actions [1]. The transnational actions of non-Party stakeholders become “the heart of the new climate regime” [2] because every sector’s participation is paramount for coping with environmental problems and attaining sustainable development goals. However, environmental
management (EM) has not been emphasized in social sectors such as public institutions, schools, and hospitals as much as in industrial sectors due to their relative contribution to environmental issues. The environmental footprint of the healthcare sector is closely related to the use of devices and chemicals to treat patients [3]. EM has not attracted the attention of hospital leadership because the principal goal of the healthcare sector is “achieving high value for patients . . . defined as the health outcomes achieved per dollar spent” [4]; EM needs to be promoted in this sector because its operation is close to the people and more likely to directly affect people’s lives.

In South Korea, there were 89,919 healthcare facilities in 2016, including hospitals, clinics, dental hospitals and clinics, oriental medical hospitals and clinics, and drugstores [5]. Korean citizens visited hospitals or clinics an average of 20.28 times in 2017 [6]. Patients and staff are at hospitals 24 h a day. Hospitals consume a lot of energy, chemicals, heavy metals, and radioactive isotopes, and they also produce various forms of waste, including biomedical wastes that can spread infectious disease if not properly managed [3,7–10]. In the United States, healthcare facilities were the second highest energy consumer, after manufacturing facilities, on the basis of electricity use per square foot [11]. The healthcare sector accounted for 8% of total CO₂ emissions in the United States [12]. In Egypt, about 39% of the hospital waste studied was hazardous [13]. The treatment of more serious illnesses requires more resources and thus generates more waste. For example, a single dialysis session consumes 500 L of water and produces 2.5 kg of solid waste [10]. Recognizing the importance of EM in the healthcare sector, the United Kingdom regularly estimates and issues data on the carbon footprint of the healthcare sector; the GHG (Greenhouse Gas) emissions of that sector have decreased by 11% from 2007 to 2015. The British healthcare sector has a separate GHG reduction target, in line with the Climate Change Act of 2008: an 80% reduction by 2050 [14].

In South Korea, medical waste generation increased by about 15% per annum from 2006 to 2015. In 2016, health facilities generated 221,592.4 tons of medical waste. Almost all medical waste was incinerated [15]; the incineration cost for medical waste was about four to five times more expensive than that of municipal waste [16]. Therefore, EM needs to be diffused in South Korean hospitals. To promote EM in the healthcare sector, policy measures such as Voluntary Agreements (VAs), the Environmental Information Disclosure System (EIDS), the Greenhouse Gas and Energy Target Management System (GETMS), and the Emission Trading System (ETS) are practiced in South Korea. By the end of 2017, 41 hospitals participated in VAs for EM [17]. By the end of 2016, 21 hospitals and 57 public healthcare institutions participated in EIDS [18]. Although the South Korean government continuously tries to diffuse EM in the healthcare sector, the status of EM and the effectiveness of these measures in the healthcare field have rarely been studied in a comprehensive manner. Many studies have focused on a specific area of EM, for example, case studies of waste management in hospitals [8,9,13,19–21]. Few studies have used a quantitative approach to investigate the performance of EM in South Korean hospitals comprehensively.

This study aims to promote and enhance EM practices in hospitals by presenting policy recommendations based on a diagnosis of current EM practices with a focus on the eco-efficiency. This study evaluates changes in the eco-efficiency of the South Korean healthcare sector based on Data Envelopment Analysis (DEA). It uses data of 21 Korean hospitals from 2012 to 2015, including water and energy consumption, waste generation, hazardous chemical use, sales, and the number of patients at individual hospitals. In addition to diagnosing EM performance at these 21 hospitals, this study surveys 29 hospital staff members who were in charge of environmental management. This study uses the analytic hierarchy process (AHP) to evaluate the relative importance and performance of individual environmental management tasks based on the questionnaire answers. This study also conducts an importance-performance analysis (IPA) to evaluate the effectiveness of EM and to develop recommendations. First, previous studies regarding environmental management in the health care sector are reviewed in the Literature Review section. Next, the methodology used (including DEA, AHP, and IPA) and datasets are explained in the Methodology and Data section. The results and
their implications are discussed in the Results and Discussion section. Finally, major findings and limitations of this study are presented in the Conclusions section.

2. Literature Review

Studies of EM in hospitals investigated the factors motivating EM in hospitals [22,23], the status of EM implementation, and the effects of policy measures such as the VAs and the ETS on EM in hospitals.

There are competitive drivers, regulatory drivers, and ethical drivers that motivate hospitals to participate in EM [22]. Hospitals introduce EM to reduce administrative costs, to improve competitiveness by differentiating themselves to the public using certificates earned through EM practices, and to attain accompanying benefits such as safety enhancement [24,25]. Hospitals also conduct EM due to external factors such as government regulations and increased pressure for social responsibility [26]. In addition to the external pressure regarding social responsibility, the willingness of top management is another ethical driver for EM. The influence of these drivers varies along with various characteristics of hospitals, such as their governance structure and ownership. For example, the greater importance of regulations at public hospitals is attributed to their governance structure [22]. In addition, size and location have been found to affect the influence of regulatory and competitive drivers on hospitals’ EM adoption and practice: expenses are perceived as more important in small hospitals than in medium ones, and even more important in large hospitals [23].

Many studies have focused on waste management in hospitals, due to the unique profile of waste generated in hospitals [8,9,13,19–21,27,28]. Almost all case studies have pointed out issues related to the inappropriate segregation of waste generated in hospitals in developing countries and argued the necessity of training or educating hospital staffs [8,9,13]. One study argued for an integrated system to dispose of waste generated in hospitals, using composting, incineration, and recycling based on an LCA (Life Cycle Assessment) analysis of various waste disposal scenarios [27]. Recognizing the huge amount of waste generated from disposable materials used in hospitals, Campion et al. (2015) conducted a life-cycle assessment of the environmental impacts of the consumption of disposable packages, which consisted of “a set of sterile, disposable products prepackaged for a specific procedure,” at 15 hospitals (12 in the United States, 2 in Thailand, and 1 in Global Links (an NGO (Non-Governmental Organization)). They then suggested an alternative green or environmentally preferred custom pack that could reduce the impact by 80% over the average disposable pack [29]. Some studies have been conducted on EM issues beyond waste management. For example, Saad (2003) focused on indoor pollutants, which can harm the health of hospital staffs and patients [30]. Carraro et al. (2016) conducted a comparative study that surveyed risks and legislation regarding hospital wastewater, finding that there are regulatory loopholes for some substances, including antibiotic residues, even in industrialized countries [20]. In addition to the waste or water, Chiarini, Opoku, and Vagnoni (2017) compared sustainable procurement practices at public hospitals in Italy and the United Kingdom by analyzing the responses to seven questions regarding sustainable procurement. They found that the Italian hospitals tended to focus on compliance with laws or regulations, while the British organizations tended to ask suppliers to improve their performance over time [31]. However, that study did not further investigate the factors that led to those differences.

Some studies have investigated or suggested a framework for EM in the healthcare sector [7,32] and have identified barriers to the spread of EM [33]. Blass et al. (2017) developed a framework that enables consistent and robust measurement and reporting of environmental performance in hospitals [7]. Rian-Fogarty et al. (2016) investigated the effectiveness and applicability of an existing EM program, the Green Campus Program, in a case study of a teaching hospital in Ireland, finding that it is a “systematic approach to environmental action and education” [32]. Seifert (2018) conducted 14 in-depth telephone interviews with people who were in charge of EM at German hospitals that participated in voluntary environmental management systems. Through this qualitative approach, they found major barriers to the system, such as the heavy initial documentation burden and lack
of knowledge and awareness across the all of the stages, including 'before initial registration', 'implementation and maintenance', and 'revalidation' [33].

Several studies have assessed EM and investigated its potential in hospitals. Faezipour and Ferreira (2018) identified factors influencing the water sustainability of three hospitals in the United States, and they modeled the causal relationship between the factors, water footprints of the hospitals, the cost of services and resources, and patient wellbeing. Water saving or water reuse was found to reduce the water footprint and cost of services and resources, and also enhance the overall wellbeing of the population that is affected by external freshwater quality [34]. Romero and Carnero (2017) established a multi-criteria model for environmental assessment of the health care sector. Their model consists of three criteria, 12 first-level sub-criteria, 46 indicators, and five alternatives. The questionnaires related to these indicators, e.g., “a value between 0 and 0.45 kg/patient of potentially infectious waste is obtained and is not removed in compliance with regulations,” could be assessed using the AHP method based on different weightings of criteria. The authors tested this model to assess the environmental management status of a Spanish hospital. With a score of 0.6286, they showed the hospital carried out its environmental management well. The hospital did particularly well on the criteria related to energy consumption, hazardous waste generation, and legal matters [35].

Similarly, environmental management in the South Korean healthcare sector has been qualitatively studied. Early studies, conducted before the introduction of various policy measures, focused on defining eco-friendly hospitals and recommending policy measures for EM in the health sector. These presented key attributes of eco-friendly hospitals based on cases in developed countries [36], provided recommendations to improve EM in hospitals based on surveys [37], and pointed out the necessity of additional policy measures to strengthen EM in hospitals in preparation for an emission trading scheme [37]. More recent studies have scrutinized a specific policy measure or assessed EM practices in hospitals using specific criteria. Kang (2013) investigated the EIDS as practiced and presented recommendations for that specific policy [38]. Kim and Kang (2014) analyzed the EM practices at 44 hospitals using green management evaluation criteria and presented recommendations for the health sector [39]. Few studies have quantitatively and comprehensively investigated the performance of EM in hospitals. Therefore, a methodology for assessing EM in the health care sector, quantitatively as well as qualitatively, needs to be established.

3. Policies and Instruments for Environmental Management in Healthcare Sector in South Korea

3.1. Brief Survey of Healthcare Sector in South Korea

The number of South Korean health facilities totaled 89,919 in 2016 (see Table 1). Most of these were clinics, dental hospitals and clinics, oriental medical hospitals and clinics, and drug stores. Hospitals are classified according to specific requirements articulated in the Medical Service Act (Act No. 8366). Whereas clinics provide medical services primarily to outpatients, hospitals should have more than 30 patient beds. General hospitals should be equipped with at least 100 patient beds. Superior general hospitals are hospitals for treating high-level diseases; they are designated by the Ministry of Health and Welfare from general hospitals that meet the special requirement of having more than 20 specialized departments. As of 2016, there were 43 superior general hospitals, 298 general hospitals, and 2942 hospitals.

Table 1. Summary statistics for the South Korean healthcare sector in 2016 [40].

| Total | Superior General Hospital | General Hospital | Hospital | Medical Clinic | Dental Hospital and Clinic | Oriental Medical Hospital and Clinic | Health Center | Drugstore |
|-------|---------------------------|------------------|---------|----------------|---------------------------|-------------------------------------|--------------|----------|
| 89,919| 43                        | 298              | 2942    | 30,292         | 17,246                    | 14,150                              | 3505         | 21,443   |

As of 2016, 221,592.4 tons of medical waste were generated from health facilities, including general hospitals, hospitals, medical clinics, public medical clinics, animal hospitals, nursing facilities, research
institutes, mortuaries and crematoria, and prisons. Almost all of this medical waste (204,752.7 tons) was incinerated; the rest was treated with sterilization shredding devices [15]. The incineration cost for medical waste was about 600–800 thousand KRW per ton (about 560 to 750 USD per ton), which was 4–5 times more expensive than the cost of incinerating municipal wastes [16].

3.2. Policies and Instruments for Environmental Management in the South Korean Healthcare Sector

Four policy measures are practiced in South Korea to promote EM in the healthcare sector: Voluntary Agreements (VAs), the Environmental Information Disclosure System (EIDS), the Greenhouse Gas and Energy Target Management System (GETMS) and the Emission Trading System (ETS).

Since 2011, the Ministry of the Environment (MOE) has taken several initiatives, including establishing guidelines for EM in the public and service sector, including the healthcare sector; holding seminars and workshops for building EM capacities; sharing best practices in the healthcare sector; supporting the establishment of domestic eco-friendly hospital networks; and organizing expert meetings [41].

The MOE has implemented VAs with large general hospitals, university hospitals, and superior general hospitals since 2013 to promote EM in the healthcare sector. Ten hospitals signed a memorandum of understanding (MOU) for a VA in 2013; this signing ceremony between the Minister of the MOE and the hospital CEOs drew much attention from the press and public. In 2014, 11 more hospitals signed a VA, followed by nine more in 2015, six more in 2016, and five more in 2017; by the end of 2017, 41 hospitals participated in a VA for EM [17]. The hospitals with a VA can use the title of “Green Hospital” in their publicity. The MOE provides them up to 10 million KRW (about 9300 USD) in financial support for EM consulting, the establishment of an eco-friendly hospital network at the domestic and global level, and sharing of best practices and solutions regarding EM.

In July 2015, the South Korean government announced that it aimed to reduce national greenhouse emissions (GHG) by 37% compared to business-as-usual (BAU) emissions by 2030 [42]. To achieve this emission reduction target, two primary policy measures are in place: the GETMS and the ETS. Companies or business sites with GHG emissions or energy consumption exceeding specific criteria (Companies with emissions exceeding 50,000 tCO$_2$eq/year or energy consumption exceeding 200 TJ/year, or business sites with emissions exceeding 15,000 tCO$_2$eq/year or energy consumption exceeding 80 TJ/year, shall participate in the GETMS.) are required to participate in these measures. Entities with more substantial emissions or energy consumption are controlled under the ETS; those with emissions or energy consumption smaller than the ETS criteria are controlled through the GETMS.

South Korea began the ETS on 1 January 2015. Tradable permits are allocated to controlled entities under the ETS according to a grandfathering principle (The whole allowance is distributed for free to the controlled entities for Phase I, from 2015 to 2017. From 2018 to 2020, 3% of the allowances are distributed through auction for Phase II). The entities must surrender permits equivalent to their emissions at the end of the year. Two hospitals, Kangnam St. Mary’s Hospital and Seoul National University Hospital, have been subject to the ETS since 2015 [43]. Four general hospitals, Yangsan Busan University Hospital, Gacheon University Gil Hospital, Jeonbuk University Hospital, and Chungnam University Hospital, are controlled under the GETMS [44]. These controlled entities must make efforts to reduce their emissions or energy consumption to meet their annual target, which is established through a bottom-up process: the individual target is determined in consultation with the MOE [45]. At the end of 2016, 346 companies and facilities were controlled under the GETMS [45].

In addition, the MOE has operated the Environmental Information Disclosure System (EIDS) to promote the implementation of VAs and communication with people, to strengthen monitoring of environmental impacts, and to increase investment in eco-friendly companies by financial institutions and investors on the basis of the environmental information submitted to the system [46,47]. MOE initiated the EIDS as a pilot project in 2010; the MOE provides participating companies with benefits such as training programs and consultations. After 2012, the EIDS was expanded to include central
government agencies, local governments, universities, public corporations, and large general hospitals and companies that have significant environmental effects [47]. These entities are required to disclose environmental information such as their business overview; plan and activity for EM; resource savings and pollution reductions; and EM attainments (e.g., EM-related awards, EM systems, or the status of the EM division) by Article 16.8 and 16.9 of the “Environmental Technology and Environmental Industry Support Act.” As of 2015, 1216 companies and organizations participated in the EIDS, including 78 hospitals and public healthcare institutions. Details on the items of environmental information to be disclosed by the healthcare sector are shown in Table A1.

Thanks to government policy measures, some achievements have been observed. The hospitals participating in VAs saved costs through reducing energy and water consumption (See Table 2). In addition to these quantitative achievements, a Green Hospital in Seoul introduced the idea of green service, which treats elderly volunteers who clean up the neighborhood for free and helps low-income elderly people using revenue collected from an annual bazaar held with environmental NGOs (interview on 11 June 2017).

Table 2. Total annual achievements by hospitals signing a voluntary agreement for environmental management in South Korea [41].

| Year   | Voluntary Agreement and Annual Achievements (Total Electricity or Water or Cost Savings and Total CO₂ Reductions) |
|--------|-------------------------------------------------------------------------------------------------------------|
| 2013 (1st) | • 10 MOUs (Memorandum of Understanding)  
             • 2010 MWh of electricity saved, 155,910 tons of water saved, 5305 tons of CO₂ reduction; consequent cost savings: 1300 Million KRW (Korean Won) |
| 2014 (2nd) | • 11 MOUs  
             • 1516 MWh of electricity saved, 47,482 tons of water saved, 1277 tons of CO₂ reduction; consequent cost savings: 500 Million KRW |
| 2015 (3rd) | • 9 MOUs  
             • 6178 MWh of electricity saved, 3188 tons of CO₂ reduction; consequent cost savings: 900 Million KRW |

Note: In the third year, information about water consumption was not collected because the VA (Voluntary Agreement) emphasized electricity and GHG (Greenhouse Gas) emissions reduction.

4. Methodology and Data

DEA measures relative efficiency by comparing the efficiencies of individual decision-making units (DMU) in targets such as governments, hospitals, companies, programs, and policy measures. It was developed by Charnes, Cooper, and Rhodes (1978) [48] to measure the concept of efficiency, as defined by Farrel in 1957. DEA finds the “efficient frontier,” which is the efficiency of the best practices; measures the “distance” of efficiency values of other DMUs from the “efficient frontier”; and provides rankings of efficiencies of individual DMUs [48,49]. As a result, potential improvements are identified for inefficient DMUs. DEA has advantages in providing information on the reference set and potential improvements that should be set as an example for inefficient units to become more efficient. Therefore, it has been widely used not only as a measure of efficiency, but also as a tool for setting goals for analysis and improvement.

Among the variants of the DEA model, this study uses an input-oriented model that aims to improve efficiency by minimizing the inputs required to achieve the targeted output [50]. The input-oriented model is more appropriate to environmental management in hospitals because it pursues enhancements in eco-efficiency by reducing inputs/environmental burdens given the desired output rather than increasing output while maintaining inputs. This study uses the input-oriented Banker, Charnes, and Cooper (BCC) model (1984) [51], allowing variable returns to scale (VRS). VRS assumes the increased outputs may or may not be proportional to the increased inputs. This differs from constant returns to scale (CRS), which assumes that the increased outputs should be proportional to the increased inputs [50]. The BCC allows measurement of technical efficiency by separating the
effects of scale [51], this is more appropriate for measuring pure technical efficiency while taking into consideration the different sizes of hospitals.

This study collected the data from all 21 hospitals that participated in the EIDS in South Korea over the period from 2012 to 2015 (see brief information on the 21 hospitals in Table 3) (The value of sales is adjusted to the 2012 value, after accounting for inflation.). First, this study analyzed four mandatory reporting items of the 20 reporting items that included quantitative information under the EIDS as input variables (see Table A1): annual water consumption (ton of water), annual energy consumption (TOE), annual waste generation (ton of waste), and annual hazardous chemical use in each hospital (kg of chemical). It used two other mandatory reporting times, the total annual sales (million Korean Won) and the number of patients (persons), as output variables. The variables can be seen in Table 4, and detailed values for each variable over the period can be found in Table A2. Only quantitative data that must be reported to the EIDS was used in order to obtain data from all of the EIDS-participating hospitals. Other qualitative information that is attainable from the EIDS was used for the additional IPA analysis.

Table 3. Brief summary of the hospital sample.

| Location (Provinces) | Public/Private | Number of Beds |
|----------------------|----------------|----------------|
| H01 Gangwon          | Public         | 15             |
| H02 Gyeongsang       | Public         | 884            |
| H03 Gyeongsang       | Public         | 616            |
| H04 Gyeongsang       | Public         | 887            |
| H05 Gyeonggi (including Seoul) | Public | 484         |
| H06 Gyeongsang       | Public         | 1227           |
| H07 Gyeongsang       | Public         | 30             |
| H08 Gyeongsang       | Public         | 100            |
| H09 Gyeonggi (including Seoul) | Private | 1101         |
| H10 Gyeonggi (including Seoul) | Private | 1989         |
| H11 Gyeonggi (including Seoul) | Public | 1786         |
| H12 Gyeongsang       | Public         | 950            |
| H13 Jeolla           | Public         | 962            |
| H14 Jeolla           | Public         | 1081           |
| H15 Jeju             | Public         | 643            |
| H16 Gyeonggi (including Seoul) | Public | 1029         |
| H17 Chungcheong      | Public         | 1268           |
| H18 Chungcheong      | Public         | 660            |
| H19 Gyeongsang       | Public         | 518            |
| H20 Chungcheong      | Public         | 414            |
| H21 Gyeongsang       | Public         | 562            |

Table 4. Variables for evaluating eco-efficiency in hospitals.

| Category (Environmental damage and resource consumption) | Unit | Details |
|--------------------------------------------------------|------|---------|
| Water consumption                                      | ton  | The quantity of water used yearly |
| Energy consumption                                      | TOE  | Total energy consumption yearly, such as electricity, gasoline, etc. |
| Waste generation                                       | ton  | The total amount of waste generated yearly |
| Chemicals consumption                                  | kg   | The total amount of hazardous chemicals used yearly |
| Sales                                                  | Million KRW | The total amount of sales yearly |
| Patients                                               | Person | Total number of patients yearly |

Eco-efficiency is defined “as being achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological
impacts and resource intensity throughout the life-cycle, to a level at least in line with the Earth’s estimated carrying capacity.” Furthermore, “progress in eco-efficiency can be achieved by providing more value per unit of environmental influence or unit of resource consumed” [52]. Eco-efficiencies are calculated and evaluated using Frontier Analyst (version 4, Banxia Software Ltd, Kendal, Cumbria, United Kingdom), a DEA software application. For example, the absolute value of eco-efficiency of H01 is estimated (see the equation below). Among the estimated eco-efficiencies of the 21 hospitals, the benchmarked or highest value is identified, and its relative eco-efficiency is set as one. As of 2015, H01 is one of the most eco-efficient hospitals, along with eight others (See Table 5). Then, the eco-efficiency values of the other hospitals are compared to the benchmarked value to establish their eco-efficiency values relative to the highest eco-efficiency value. A smaller value means relatively lower eco-efficiency:

\[
\text{Eco - Efficiency} = \frac{\text{Economic value} - \text{added}}{\text{Environmental Damage}}
\]

In addition, this study surveyed 51 hospital staffs about EM (the 21 hospitals whose eco-efficiencies were assessed by DEA in this study and an additional 30 hospitals participating in the eco-friendly hospital network). The questionnaire used a symmetrical 5-point Likert scale to ask about the relative importance of individual reporting items of the EIDS as major management indicators with respect to EM diffusion in hospitals (see Table A3 for the detailed questionnaire). The reporting items are grouped into four categories: environmental management (or procurement) system establishment; resource/energy management and reduction activities; greenhouse gas emissions and environmental pollution management and reduction activities; and social/ethical responsibility compliance. There are specific items under each individual category (e.g., within the category of social/ethical responsibility compliance, there are three specific questions on the relative importance of domestic and international environmental regulation compliance vs. sustainability report publication, domestic and international environmental regulation compliance vs. responses to stakeholder requests for environmental information; and sustainability report publication vs. responses to stakeholder requests for environmental information). The questionnaire also asked about the performance of EM tasks for 13 items (Of 20 information disclosure items for the South Korean healthcare sector, items analysed in the DEA analysis were excluded when constructing the questionnaires.) that should be reported to the EIDS in individual hospitals. The questionnaire was emailed to the 51 hospital staffs on 8 May 2017; and 33 responses were received by 15 May 2017. These responses to the multi-criteria decisions were assessed using AHP to solve multi-criteria complex problems. The AHP allows the respondents, the staff responsible for environmental management in these hospitals, to evaluate the relative importance of items through pairwise comparison [53]. Among 33 responses, 29 responses with a consistency ratio smaller than 0.1 were analyzed. Saaty (1980) proposed a consistency index to evaluate the level of consistency of final decisions among respondents [54]. Generally, if the consistency index is less than 0.1, the consistency of the pairwise comparison matrix is considered to be good and reliable. The responses to the questionnaires were analyzed using the importance-performance analysis (IPA) matrix. This study draws this matrix using SPSS 18 (IBM, Armonk, NY, USA). The IPA is a technique for diagnosing the performance of services or products, comparing performance to their importance and suggesting insights into priorities [55]. Specifically, services or products located in quadrant 4 of the IPA matrix—the service or product is highly important, but performance is low—should receive more focus [56] (see Figure 1).
5. Results and Discussion

5.1. DEA Results

Table 5 presents the changes in eco-efficiency from 2012 to 2015. The variance in the average differences of the eco-efficiency scores was statistically significant at the 5% level, as seen in Table 6.

The average eco-efficiency of the 21 hospitals was 0.940 in 2015. The eco-efficiency of 12 hospitals was 1.0, which means that those hospitals were the most efficient. Among these hospitals, four hospitals participated in government regulation through the GETMS. The other nine hospitals were less eco-efficient than the 12 benchmarked hospitals. The average eco-efficiency score rose from 2012 (0.830) to 2014 (0.933) but then dropped slightly in 2015 (0.902). The gradual increase in average eco-efficiency from 2012 to 2014 shows improvements at the relatively less eco-efficient hospitals. In contrast, the slight decrease in 2015 implies regression by the less eco-efficient hospitals. H11, H12, H14, and H17 participated in government regulation through the GETMS; these hospitals showed gradual improvement in their eco-efficiency scores from 2012 to 2015. The scores at H11, H12, and H17 had been particularly lower in 2012. The notable improvement of their eco-efficiency, up to 1.0 in 2015, can be attributed to the implementation of the GETMS.

Table 5. Eco-efficiencies of 21 hospitals from 2012 to 2015.

| Hospital | Year/Eco-Efficiency | Remarks |
|----------|---------------------|---------|
|          | 2012    | 2013    | 2014    | 2015    |         |
| H01      | 1.000   | 1.000   | 1.000   | 1.000   | -       |
| H02      | 0.770   | 0.866   | 0.785   | 0.819   | VA (2013) |
| H03      | 0.760   | 0.870   | 1.000   | 1.000   | -       |
| H04      | 0.715   | 0.722   | 0.797   | 0.761   | -       |
| H05      | 0.630   | 0.675   | 0.814   | 0.570   | VA (2015) |
| H06      | 0.816   | 0.815   | 0.864   | 0.826   | -       |
| H07      | 0.830   | 1.000   | 0.982   | 0.771   | -       |
| H08      | 0.997   | 1.000   | 1.000   | 0.905   | -       |
| H09      | 0.905   | 0.829   | 0.897   | 1.000   | -       |
| H10      | 0.993   | 1.000   | 1.000   | 0.918   | -       |
| H11      | 0.592   | 0.824   | 1.000   | 1.000   | GETMS   |
| H12      | 0.663   | 0.927   | 0.961   | 1.000   | GETMS   |
| H13      | 1.000   | 0.757   | 0.842   | 0.867   | -       |
| H14      | 0.703   | 0.904   | 0.936   | 0.946   | GETMS   |
| H15      | 0.646   | 0.857   | 0.958   | 0.681   | -       |
| H16      | 1.000   | 1.000   | 1.000   | 1.000   | -       |
Although H02 and H05 participated in VAs, their eco-efficiencies not only did not improve, but became even worse. This means that these two hospitals preserved the status quo or regressed regarding EM while other hospitals improved their eco-efficiencies. This result makes the effectiveness of VAs questionable, shows that VAs cannot guarantee that hospitals will execute activities or practices for EM, and implies that VAs have limitations in their current form and need corrective measures such as strict monitoring, reporting, and a feedback system.

**Table 6. Statistics of variances of eco-efficiency scores.**

| Total Sum of Squares | Degrees of Freedom | Mean Square Error | p-Value |
|----------------------|--------------------|-------------------|---------|
| 0.272                | 1.000              | 0.091             | 0.0001  |

The potential for improvement was evaluated for hospitals with lower eco-efficiency scores by comparing their actual production conditions and processes with hospitals that had the same production conditions and processes. Figure 2 shows the potential improvements that are achievable at nine inefficient hospitals. They could reduce water consumption by eight percentage points (ppt), energy consumption by 9 ppt, waste generation by 10 ppt, and hazardous chemical use by 24 ppt, to be in line with the most efficient hospitals. Notably, there is a significant room to reduce hazardous chemical use in less eco-efficient hospitals.

**Figure 2. Potential improvements by variables in 2015.**

By analyzing the potential improvements at hospitals with low eco-efficiency scores, each hospital could identify which input variables needed to be improved. In addition, more substantial alternatives need to be reviewed and adjusted to achieve an eco-efficiency score of 1.0.

5.2. IPA Results

Table 7 presents the results of a combined weighting analysis of the responses to the questionnaires that asked about the relative importance of the individual EIDS reporting items for EM in hospitals.
Of 33 collected responses, four responses with a consistency ratio larger than 0.1 were excluded [54]: thus, a total of 29 responses were analyzed. As a result of the combined weighting analysis, it was found that the hospital staffs recognized “management of energy use and reduction activity” as the most important EIDS reporting item for diffusing EM. In addition, the scores for “the establishment of a vision and strategy of EM”, “organization of task team for EM and task assignment”, “management of water use and reduction activity”, and “management of GHG emissions and reduction activity” are greater than the average score of 0.077. This implies that these items are recognized as the highest priorities for promoting EM in the healthcare sector.

Table 7. Comprehensive results of the combined weighting analysis of relative importance of EIDS reporting items.

| Category                                      | EIDS Reporting Items                                           | Score | Ranking |
|-----------------------------------------------|---------------------------------------------------------------|-------|---------|
| Environmental management (or procurement) system establishment | 1. Establishment of a vision and strategy for environmental management | 0.107 | 4       |
|                                               | 2. Organization of task team for environmental management and task assignment | 0.124 | 2       |
|                                               | 3. Guideline and compliance with green purchasing             | 0.059 | 9       |
| Resource/energy management and reduction activities | 1. Management of water use and reduction activity              | 0.122 | 3       |
|                                               | 2. Management of energy use and reduction activity             | 0.146 | 1       |
|                                               | 3. Investment in new and renewable energy and the introduction of technology | 0.048 | 11      |
| GHG emissions and environmental pollution management and reduction activities | 1. Management of GHG emissions and reduction activity         | 0.091 | 5       |
|                                               | 2. Management of water pollutants and reduction activity       | 0.055 | 10      |
|                                               | 3. Management of waste generation and reduction activity       | 0.066 | 7       |
|                                               | 4. Management of hazardous chemical use and reduction activity | 0.071 | 6       |
| Social/ethical responsibility compliance      | 1. Compliance with domestic and international environmental laws and regulations | 0.062 | 8       |
|                                               | 2. Publication of environmental report and environmental information disclosure | 0.030 | 12      |
|                                               | 3. Response to stakeholder requests for environmental information | 0.021 | 13      |
| Average                                       |                                                               | 0.077 | -       |

Note: The EIDS stands for the Environmental Information Disclosure System.

The results of the relative performance of individual EIDS reporting items are shown in Table 8. It was found that “compliance with domestic and international environmental laws and regulations,” “management of waste generation and reduction activity,” “management of energy use and reduction activity,” and “management of water use and reduction activity” scored the highest: 4.20, 4.10, 4.10, and 4.00, respectively. Scores were lower for “investment in new and renewable energy and introduction of technology,” “publication of environmental report and disclosure,” “organization of task team
for EM and task assignment,” “response to stakeholder requests for environmental information,” and “guideline and compliance with green purchasing.”

Table 8. Relative performance of EIDS reporting items.

| EIDS Reporting Items                                             | Score | Ranking |
|-----------------------------------------------------------------|-------|---------|
| 1. Establishment of a vision and strategy for EM                 | 3.60  | 9       |
| 2. Organization of task team for EM and task assignment          | 3.50  | 11      |
| 3. Guideline and compliance with green purchasing                | 3.70  | 7       |
| 4. Management of water use and reduction activity                | 4.00  | 4       |
| 5. Management of energy use and reduction activity               | 4.10  | 2       |
| 6. Investment in new and renewable energy and the introduction of technology | 3.30  | 12      |
| 7. Management of GHG emissions and reduction activity            | 3.70  | 7       |
| 8. Management of water pollutants and reduction activity         | 3.80  | 5       |
| 9. Management of waste generation and reduction activity         | 4.10  | 2       |
| 10. Management of hazardous chemical use and reduction activity  | 3.80  | 5       |
| 11. Compliance with domestic and international environmental laws and regulations | 4.20  | 1       |
| 12. Publication of environmental report and environmental information disclosure | 3.30  | 12      |
| 13. Response to stakeholder requests for environmental information| 3.60  | 9       |
| Average                                                         | 3.75  | -       |

Using the results for importance and performance, the IPA matrix was constructed (see Figure 3). “Management of water use and reduction activity” and “management of energy use and reduction activity” were in the first quadrant, which means that the current state needs to be maintained because both the importance and the performance of the tasks are high. Tasks located in the second quadrant should be priorities because the activity is important, but its performance is low. “Establishment of a vision and strategy for EM,” “organization of task team for EM and task assignment,” and “management of GHG emissions and reduction activity” fall in this area of “concentrate here.” In contrast, “guideline and compliance with green purchasing,” “investment in new and renewable energy and introduction of technology,” “publication of environmental report and environmental information disclosure,” and “response to stakeholder requests for environmental information” have low priorities, which means that both the performance and importance of tasks are low: these tasks are less emphasized. In the fourth quadrant (“possible overkill” area), tasks are relatively unimportant, but a great deal of effort is concentrated on them; unnecessary work should be discarded. “Management of emissions of water pollutants and reduction activity,” “management of waste generation and reduction activity,” “management of hazardous chemicals use and reduction activity,” and “compliance with domestic and international environmental regulations” were included in this quadrant.

Comparison of the relative importance of environmental input variables for 2015 enables us to deepen the analysis of eco-efficiency. Water use (0.762) and energy consumption (0.754) are placed in the fourth quadrant because the eco-efficiencies of these two environmental input variables were higher than the average. On the other hand, the eco-efficiency scores of waste generation (0.532) and hazardous chemicals use (0.323) were lower than average, as were their importance levels. This result reveals the gap between actual performance (eco-efficiency measured by the individual environmental input variable) and the recognized performance (responses to the relative performance of corresponding activities). More specifically, hospital staff did not recognize the management of waste generation and hazardous chemical use as priorities; instead, they believed that their performance on those items was excellent because waste and hazardous chemical measures practiced in hospitals are straightforward and easy to mobilize staff for participation. In contrast, the actual eco-efficiency or performance of these items is lower, due to the large gap with the superior performance of hospitals regarding management of waste and hazardous chemical use. This result implies that it is necessary to adjust or raise the level of hospitals’ reduction targets so they can be more eco-efficient.
excellent because waste and hazardous chemical measures practiced in hospitals are straightforward. Further, for proactive approaches such as the introduction of innovative technologies or the development of alternatives. The existing approach to hazardous chemical use in the healthcare sector is somewhat reactive, focusing on how to effectively separate and safely dispose of hazardous wastes. The existing approach to hazardous chemical use in healthcare sector is somewhat reactive, focusing on how to effectively separate and safely dispose of hazardous wastes. This room for improvement implies the necessity of proactive approaches such as the introduction of innovative technologies or the development of alternatives.

Based on the IPA results, priorities for EM in the healthcare sector were identified, areas in which performance is low even though the tasks are essential. Interestingly, “establishment of a vision and strategy for environmental management” and “organization of task team for environmental management and task assignment” are included in these priorities. As Garcia et al. (2015) argued, changes in management bring challenges such as time and cost [10], which are likely to slow down the spread of EM in the healthcare sector. Therefore, know-how and best practices need to be shared to...
enable followers to get past the challenges more smoothly. The government needs to support building a network or platform for sharing knowledge among hospitals. In addition, the government should focus on training and improving awareness of these priorities.

Based on quantitative analysis of reported data and qualitative analysis using responses to questionnaires, this study assessed EM in South Korean hospitals and provides implications for improving policy measures to diffuse EM in South Korean hospitals. The methodological approach sheds light for researchers interested in EM in the healthcare sector because previous studies depended more on qualitative approaches, particularly case studies. However, the number of analyzed hospitals is too small to represent all the hospitals in South Korea due to the limited availability of the data. Furthermore, because this study surveyed staffs at the 21 hospitals that participated in the EIDS program, the hospitals that did not participate in the EIDS were not represented. Additional analysis to investigate the status and performance of EM at those hospitals needs to be conducted shortly.

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Appendix A

Table A1. Environmental information disclosure items for the healthcare sector in South Korea.

| Category                          | Item                                                                 | Classification |
|-----------------------------------|----------------------------------------------------------------------|----------------|
| 1. Current status                 | 1. Annual sales                                                     | Mandatory      |
|                                   | 2. The total annual number of patients                              | Mandatory      |
|                                   | 3. Environmental award-winning and agreement                        | Voluntary      |
| 2. Green management system        | 4. Environmental management visions, strategies, measures, and goals | Voluntary      |
|                                   | 5. Dedicated organization, educational training, and internal evaluation | Mandatory     |
|                                   | 6. Green purchasing guidelines and practices status                 | Voluntary      |
| 3. Resource/energy                | 7. Investments in raw material/water/energy saving and introduction of relevant technology | Voluntary      |
|                                   | 8. Annual water consumption                                         | Mandatory      |
|                                   | 9. Annual energy consumption                                        | Mandatory      |
|                                   | 10. Investment in new renewable energy and introduction of relevant technologies | Voluntary     |
| 4. GHG/environment pollution      | 11. Investment in GHG (Greenhouse gas) mitigation and introduction of relevant technology | Voluntary      |
|                                   | 12. GHG management levels and emission intensities                  | Voluntary      |
|                                   | 13. Investments in environmental pollution reduction and introduction of relevant technology | Voluntary     |
|                                   | 14. Environmental pollution management facility and monitoring system | Voluntary      |
|                                   | 15. Annual emissions of water pollutants                            | Voluntary      |
|                                   | 16. Annual waste generation                                         | Mandatory      |
|                                   | 17. Annual harmful chemical usage                                   | Mandatory      |
| 5. Social/ethical responsibility   | 18. Violation of domestic or international environmental laws and regulations | Mandatory      |
|                                   | 19. Publication of environmental (sustainability) report             | Voluntary      |
|                                   | 20. Response to stakeholder requests for environmental information   | Voluntary      |

Source: retrieved from the EIDS web page [18].
Table A2. Values of six variables at 21 hospitals from 2012 to 2015. Unit of measurement: Water (ton); Energy (TOE); Chemicals (kg); Sales (million KRW); Patients: (persons).

| Items | H01 2012 | H02 2012 | H03 2012 | H04 2012 | H05 2012 | H06 2012 | H07 2012 | H08 2012 | H09 2012 | H10 2012 | H11 2012 | H12 2012 | H13 2012 | H14 2012 | H15 2012 | H16 2012 | H17 2012 | H18 2012 | H19 2012 | H20 2012 | H21 2012 |
|-------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Water | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     |
| Energy| 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     |
| Waste | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     |
| Chemicals| 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 |
| Sales | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     | 2012     | 2013     | 2014     | 2015     |
| Patients| 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 | 2012 | 2013 | 2014 | 2015 |

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Table A3. Questionnaire of survey for importance-performance analysis.

(Importance survey) Please indicate the degree of importance of each item as a key management indicator for spreading environmental management of hospitals.

| Category | More Importance Than | Equal | Less Importance Than | Category |
|----------|----------------------|-------|----------------------|----------|
| Environmental management (or procurement) system establishment | 5 4 3 2 | 1 2 | 3 4 5 | Resource/energy management and reduction activities |
| Environmental management (or procurement) system establishment | 5 4 3 2 | 1 2 | 3 4 5 | GHG emissions and environmental pollution management and reduction activities |
| Environmental management (or procurement) system establishment | 5 4 3 2 | 1 2 | 3 4 5 | Social/ethical responsibility compliance |
| Resource/energy management and reduction activities | 5 4 3 2 | 1 2 | 3 4 5 | GHG emissions and environmental pollution management and reduction activities |
| Resource/energy management and reduction activities | 5 4 3 2 | 1 2 | 3 4 5 | Social/ethical responsibility compliance |
| GHG emissions and environmental pollution management and reduction activities | 5 4 3 2 | 1 2 | 3 4 5 | Social/ethical responsibility compliance |

| Item | Environmental management (or procurement) system establishment category | More Importance Than | Equal | Less Importance Than | Item |
|------|-----------------------------|----------------------|-------|----------------------|------|
| Establishment of a vision and strategy for environmental management | 5 4 3 2 | 1 2 | 3 4 5 | Organization of task team for environmental management and task assignment |
| Establishment of a vision and strategy for environmental management | 5 4 3 2 | 1 2 | 3 4 5 | Guideline and compliance with green purchasing |
| Organization of task team for environmental management and task assignment | 5 4 3 2 | 1 2 | 3 4 5 | Guideline and compliance with green purchasing |

| Item | Resource/energy management and reduction activities category | More Importance Than | Equal | Less Importance Than | Item |
|------|------------------------------------------------------------|----------------------|-------|----------------------|------|
| Management of water use management and reduction activity | 5 4 3 2 | 1 2 | 3 4 5 | Management of energy use and reduction activity |
| Management of water use management and reduction activity | 5 4 3 2 | 1 2 | 3 4 5 | Investment in new and renewable energy and the introduction of technology |
| Management of energy use and reduction activity | 5 4 3 2 | 1 2 | 3 4 5 | Investment in new and renewable energy and the introduction of technology |

| Item | GHG emissions and environmental pollution management and reduction activities category | More Importance Than | Equal | Less Importance Than | Item |
|------|------------------------------------------------------------------------------------------------|----------------------|-------|----------------------|------|
| Management of GHG emissions and reduction activity | 5 4 3 2 | 1 2 | 3 4 5 | Management of water pollutants and reduction activity |
| Management of GHG emissions and reduction activity | 5 4 3 2 | 1 2 | 3 4 5 | Management of waste generation and reduction activity |
| Management of GHG emissions and reduction activity | 5 4 3 2 | 1 2 | 3 4 5 | Management of hazardous chemical use and reduction activity |
| Management of water pollutants and reduction activity | 5 4 3 2 | 1 2 | 3 4 5 | Management of waste generation and reduction activity |
| Management of water pollutants and reduction activity | 5 4 3 2 | 1 2 | 3 4 5 | Management of hazardous chemical use and reduction activity |
Table A3. Cont.

| Management of waste generation and reduction activity | Management of hazardous chemical use and reduction activity |
|------------------------------------------------------|----------------------------------------------------------|
| Item More Importance Than | Equal | Less Importance Than | Item More Importance Than | Equal | Less Importance Than | Item More Importance Than | Equal | Less Importance Than |
| Compliance with domestic and international environmental laws and regulations | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | Publication of environmental report and environmental information disclosure |
| Compliance with domestic and international environmental laws and regulations | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | Response to stakeholder requests for environmental information disclosure |
| Publication of environmental report and environmental information disclosure | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | Response to stakeholder requests for environmental information |

(Performance survey) Please indicate the extent to which your hospital has achieved the following environmental management activities.

| Items | Do You Think That We Are Promoting Environmental Management Activities Well? |
|-------|---------------------------------------------------------------------------|
|       | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 1. Establishment of a vision and strategy for environmental management | 1 | 2 | 3 | 4 | 5 |
| 2. Organization of task team for environmental management and task assignment | 1 | 2 | 3 | 4 | 5 |
| 3. Guideline and compliance with green purchasing | 1 | 2 | 3 | 4 | 5 |
| 4. Management of water use and reduction activity | 1 | 2 | 3 | 4 | 5 |
| 5. Management of energy use and reduction activity | 1 | 2 | 3 | 4 | 5 |
| 6. Investment in new and renewable energy and the introduction of technology | 1 | 2 | 3 | 4 | 5 |
| 7. Management of GHG emissions and reduction activity | 1 | 2 | 3 | 4 | 5 |
| 8. Management of water pollutants and reduction activity | 1 | 2 | 3 | 4 | 5 |
| 9. Management of waste generation and reduction activity | 1 | 2 | 3 | 4 | 5 |
| 10. Management of hazardous chemical use and reduction activity | 1 | 2 | 3 | 4 | 5 |
| 11. Compliance with domestic and international environmental laws and regulations | 1 | 2 | 3 | 4 | 5 |
| 12. Publication of environmental report and environmental information disclosure | 1 | 2 | 3 | 4 | 5 |
| 13. Response to stakeholder requests for environmental information | 1 | 2 | 3 | 4 | 5 |

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