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A scientometrics study on green building: A DEA application

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A B S T R A C T

Construction operations are blamed as one of important causes of green gas effects. During the past few decades, there has been tremendous efforts to reduce the negative effects of construction operations on environment. This paper presents an application of data envelopment analysis to measure the relative efficiencies of the researches accomplished by various countries around the world on green construction or green management. The study expects countries that produce higher amount of CO_2 accomplish more quality research articles. To do this, the study performs a survey using three keywords; namely "green construction", "green building" and "sustainable building" on Scopus database and found 8692 articles over the period 1965-2019 where one of these keywords, at least, was used in their abstracts, keywords or titles. We also use three measures of *h*-index, *I*-10 and total publications representative of quality and quantity of the outputs produced by researchers. The study considers 28 countries responsible for at least 90% of CO_2 emission for measuring the relative efficiency program using data envelopment analysis. The results indicate that Hong Kong was the only efficient country followed by Singapore with relative efficiency of 0.67.

1. Introduction

Green building, green construction or sustainable building are some common words associated with a structure and the application of processing it which are environmentally friendly and efficient throughout a building's life-cycle. Green building covers all operations from planning to design, construction, operation, maintenance, renovation, and demolition operations of the buildings (Meyer, 2009). To reach this objective, we need to build a good relationships among the contractor, the architects, the engineers, and the clients through different stages of the constructions (Ding, 2008). Green building combines various efforts to reduce and ultimately to eliminate the effects of buildings on the environment and human's healthcare. It takes advantage of renewable resources such as sunlight through passive solar, plants and trees through green roofs, rain gardens, and reduction of rainwater run-off to save electricity. There are literally various techniques used such as low-impact building materials or permeable concrete to enhance replenishment of ground water (Ortiz et al., 2009).

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During the past few decades, there have been tremendous efforts on green building (Kuo & Sullivan, 2001). Zuo and Zhao (2014) presented a comprehensive review on green building. Shaikh et al. (2014) presented a state-of-the-art review on optimized control systems for building energy and comfort management of smart sustainable buildings. Evins (2013) studied on all computational optimization techniques implemented for sustainable building design. Wang et al. (2005) presented a multi-objective optimization model to help designers in green building design by considering. Ali and Al Nsairat (2009) shed light on the concept of green building evaluation technique and its effect for reaching sustainable development through developing an effective green building rating system for residential units in Jordan. Corinaldesi and Moriconi (2009) investigated the effect of mineral additions on the performance of 100% recycled aggregate concrete. They concluded that satisfactory concrete properties is under development in different industries with recycled fine by choosing appropriate combination of the concrete materials. Leaman and Bordass (2007) discussed whether explored sources of occupant dissatisfaction, and whether or not green buildings were perceived as better method by their users and concluded that users most likely tolerate deficiencies rather more than they did with more conventional buildings.

2. The proposed study

This paper implements data envelopment analysis (DEA) to measure the relative efficiency of similar possibly non-financial units (Charnes et al., 1984; Lertworasirikul et al., 2003; Halkos & Salamouris, 2004; Adler et al., 2002). The survey looks at various inputs and outputs and by considering some weights for the inputs/outputs, measures the relative efficiency of various units. DEA has been extensively implemented for studies in green building (Zhou et al., 2013). Vyas et al. (2017) used DEA technique for benchmarking green building attributes to reach cost effectiveness. Liu et al. (2019) used DEA for the coordinated development of green building. Liu (2015) used DEA method for a green building evaluation modeling. The proposed model of this paper uses a DEA model to do a scientometrics study on efforts accomplished by authors from different countries. Fig. 1 shows the structure of the proposed study of this paper.

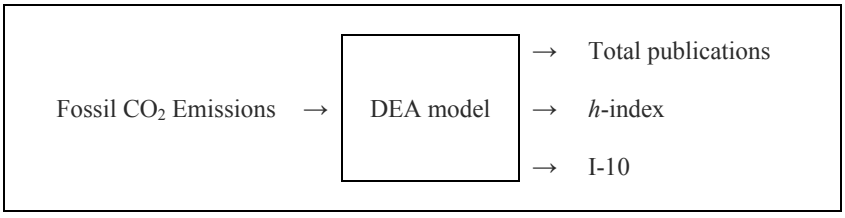

Fig. 1. The structure of the proposed method

As we can see from the results of Fig. 1, Fossil CO_2 emissions in million ton per year is taken into account as the input, which means the more CO_2 emissions generated by a country, the stronger commitment for doing research on carbon dioxide emission. The proposed method also determines three outputs as scientometrics data; namely total publications to measure quantity, *h*-index and *I*-10, as a quality of research works, for measuring the effects of the studies published by each country. The output "Total publications" covers all papers published indexed in Scopus database over the period 1959-2019 with one of the keywords of "green construction", "sustainable building" "green building" in the title, keyword or abstract. Our survey has determined 8692 records of data. Next, we filtered the data based on each country and determined *h*-index and *I*-10 statistics. In our survey, the number of publications with at least 10 citations represents *I*-10 index while *h*-index is defined as the maximum value of *h* such that the given author(s) has published *h*-articles that have been cited at least *h* times (McDonald, 2005).

Table 1 presents the summary of the data implemented for the proposed study of this paper. According to Table 1, the United States has published 2084 articles where the country has published at least 62 articles received 62 times of citations and maintains 405 articles where each article has

received at least 10 citations. The country produced 5,107.39 million ton CO_2 in 2017. These 28 countries have produced about 90% of the fossil emissions per year 2017. Thus, it is important to learn how serious they are in doing research for reducing the effect of green gas effect. The implementation of DEA has provided the relative efficiency of 28 countries and Fig. 2 presents the results of our survey.

Table 1
The summary of the input/output data

Country	Mt CO_2/Year Fossil Emission Per year 2017*	Total publication	h-index	I-10
China	10,877.22	1377	38	146
United States	5,107.39	2084	62	405
India	2,454.77	284	16	24
Russia	1,764.87	63	7	3
Japan	1,320.78	95	12	17
Germany	796.529	221	25	46
South Korea	673.324	170	19	33
Iran	671.45	56	7	7
Saudi Arabia	638.762	48	10	12
Canada	617.301	339	37	91
Indonesia	511.327	92	6	4
Mexico	507.183	18	4	1
Brazil	492.791	83	13	11
South Africa	467.654	67	10	10
Turkey	429.563	104	12	10
Australia	402.253	387	29	105
United Kingdom	379.15	504	41	140
Italy	361.176	298	28	69
France	338.193	96	16	23
Poland	319.028	94	6	3
Spain	282.364	129	18	11
Taiwan	279.74	229	17	29
Thailand	279.296	45	7	7
Kazakhstan	266.207	5	1	0
Malaysia	258.783	387	19	45
Egypt	258.668	88	9	7
Netherland	174.770	136	22	40
Hong Kong	44.715	231	33	97
Singapore	55.018	131	27	39

*https://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions

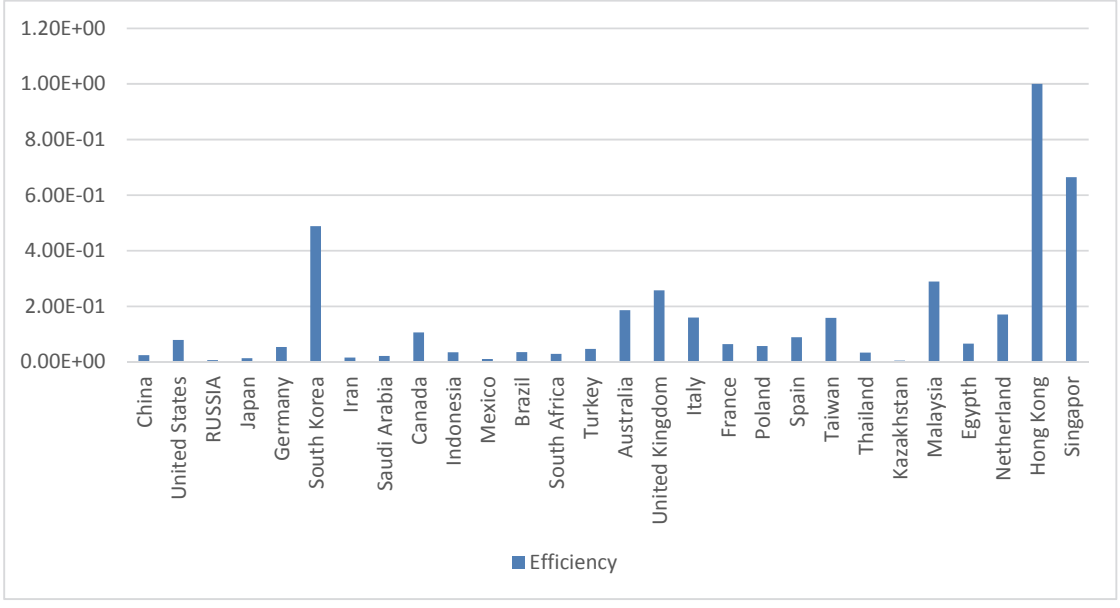

Fig. 2. The results of measuring the relative efficiency of different countries

3. Discussion

According to the results of Fig. 2, Hong Kong has been considered efficient compared with other countries in terms of presenting higher good quality papers generating less than one percent of total carbon dioxide emissions (Zhang et al., 2011; Li et al., 2006). It means that Hong Kong based researchers have been more serious about global warming. On contrast, China and the United States which are responsible for about 55% of global carbon dioxide emissions have performed poorly in terms of contributing high quality achievements for scientific society. The other observations is that some developing countries such as Singapore (efficiency = 0.67), South Korea (efficiency =0.49) and Malaysia with relative efficiency of about 0.29 have maintained fair contribution to scientific community despite the fact that they were not blamed by generating significant amount of CO_2 emissions. China produced about 5107 million ton CO_2 in 2017 which is almost half of the pollution generated by China but maintained an efficiency of about 24%. Although the number seems to be better than the United States with an efficiency of 7.8% but it is about the same as many other European countries such as United Kingdom with relative efficiency of 0.26 and Netherland with relative efficiency of 0.17. The results have shown that China and United States which are representative for more than half of green gas effect are not as serious as many other developing or developed countries for supporting scientific studies on green building.

In terms of high quality papers from Hong Kong, Qi et al. (2010) identified important factors influencing contractors to adopt green construction practices. They reported that managerial concern was the most important driver for the adoption of green practices. They also found a significant relationships between government regulations and business size with the adoption of green construction practices. According to Chan et al. (2009), green building (GB) is associated with sustainability and GB and the concept of sustainability need to be investigated for environmental concerns since their business rationale and related social concerns need to be fully explored. Chan et al. (2009) reviewed the situation of GB market in association with the general building market from the perspective of building designers. Moreover, the factors which enhance the GB were explored and the barriers which hinder its market were investigated. Chau et al. (2010) performed an investigation to estimate the effect of green experience on preferences and willingness-to-pay for green building attributes on some experiments. Tam et al. (2004) performed an investigation on green construction assessment for environmental management in the construction industry.

3. Conclusion

This paper has presented an implementation of DEA method to compute the relative efficiency of 28 countries which are accounted for at least 80% of carbon dioxide emissions. The study has attempted to measure the impacts of high quality articles in this area using two scientometrics figures; namely *h*-index and *I*-10. The results have disclosed that while many developing countries such as Hong Kong, Singapore and Malaysia have successfully contributed scientific achievements on green building, many developed countries such as China and United States have performed poorly. It happens that some selected European countries have been published quality articles on sustainable buildings. Singapore was an Asian country with efficient scientific production in terms of publishing high quality articles. The researchers have maintained a relative efficiency of 0.67 which is the second best efficiency measure after Hong Kong. Hwang and Tan (2012), for instance, presented barriers in front of having sustainable green buildings by applying a comprehensive survey in Singapore on green building project management. Overall, it appears that Asian researchers have shown more commitment on green buildings in sustainability compared with the rest of the world.

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