PEOPLE: International Journal of Social Sciences
ISSN 2454-5899

Application of Data Envelopment Analysis and Malmquist Index on the Measurement of Efficiency and Productivity: A Case Study of Rubber Production in Southern Thailand

Surakiat Parichatnon

Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, No. 1, Shuefu Road, Neipu, Pingtung, 91201, Taiwan, surakiat.parichatnon@gmail.com; zriang_vespa64@hotmail.com

Kamonthip Maichum

Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, No. 1, Shuefu Road, Neipu, Pingtung, 91201, Taiwan, kamonthip.maichum@gmail.com; mull_milk@hotmail.com

Ke-Chung Peng

Department of Agribusiness Management, National Pingtung University of Science and Technology, No. 1, Shuefu Road, Neipu, Pingtung, 91201, Taiwan, kchung@mail.npust.edu.tw

---

Abstract

The purpose of this study is to investigate the relative technical efficiency of rubber production in Southern of Thailand using the Data Envelopment Analysis (DEA) during the period 2007–2016. Moreover, Malmquist productivity index (MPI) was used to investigate the changes of rubber production efficiency and estimates of the rubber productivity trend. The findings indicated that Trang city has most effective and suitable for the production of rubber when compared to other cities in Southern Thailand. On the other hand, the results also showed that Phuket city has worst scores of efficiency and declination of rubber production. Moreover, MPI model showed the upward productivity trend of rubber production during the time period of the study. The findings from this study can provide important information to farmers, rubber research institutes and Thai government for determining effective strategies to improve productivity and technical efficiency of rubber production. Thai government and rubber research institutes should provide the knowledge, management skills and correct production skills for rubber farmers. Furthermore, rubber research institutes should be at the forefront to increase the rubber yields and provide funding to farmers for increase sustainable rubber production.

Available Online at: http://grdspublishing.org/journals-PEOPLE-home

Keywords

Data Envelopment Analysis, Malmquist productivity index, Rubber production, Southern Thailand, Technical efficiency

1. Introduction

Rubber is one of the most important crops in tropical regions around the world, especially in Southeast Asia. Around 75% of global production comes from Thailand, Indonesia and Malaysia. Thailand is the world's No. 1 rubber producer and is mostly grown in southern of the country. In 2015, Thailand's rubber production was 4.5 million tons or 35.7% of total world production and the major export markets for Thai rubber are China (50 %) followed by Malaysia (13%), Japan (8%) and South Korea (5%) (Rubber Research Institute of Thailand (RRIT), 2016). In 2016, Rubber tapping area in Thailand was 3.2 million ha, located mainly in southern Thailand (62.5%) (Rubber Research Institute of Thailand (RRIT), 2016). Increasing trend of rubber planting is a strategy related to sustainable development (Longpichai, Perret, & Shivakoti, 2012). Consequently, the efficiency measurement is necessary to estimate the production frontier for assessing the efficiency among different areas. Several optimization techniques have been tried by previous researchers. Singh, Singh, and Singh (2004) used linear programming model to optimize of wheat production in India. Chauhan, Mohapatra, and Pandey (2006) studied data envelopment analysis (DEA) method to measure efficiency on the farms. Measurement of efficiency is based on physical factors, input and output variables; which is consistent with several studies (De Koeijer, Wossink, Struik, & Renkema, 2002; Longpichai et al., 2012). Performance measurement is acquired based on the difference in available stocks of labor force, fertilizer, quantity of rubber and other characteristics where rubber production occurs (Mustapha, 2011). This study aims to measure the technical efficiency (TE) and to measure the trend of Thai rubber productivity's change during the years 2007-2016 by using DEA approach and Malmquist productivity index (MPI).

DEA approach is a non-parametric method used for the measurement of TE of agricultural productivity. DEA is a method based on applications of linear programming and the most suitable method for measuring the efficiency of decision making units (DMUs). Mustapha

(2011) measured the efficiency of rubber smallholders in Malaysia. The study used DEA method and had two inputs (cultivated area and tapping area) and one output (rubber quantity). The result showed that 23% of the total cultivators achieved 0.950-1.000 of TE score. Kumarasinghe and Patalee (2012) analyzed the TE of rubber smallholders in Sri Lanka by using DEA model and the results showed that the mean TE of rubber smallholding sector was 49.8%, which indicates that the output could be increased by 50.2% if all farmers achieved full TE. Several researchers have pointed that MPI have been developed for evaluating total factor productivity change (TFP), efficiency change (EC), and technical change (TC) (Y. Liu et al., 2015; Xue, Shen, Wang, & Lu, 2008). Furthermore, Nomikos and Pouliasis (2011) evaluated the performance of rubber industry in India from 1979-1980 to 2008-2009. The results showed that the growth rate of rubber production decreased during the time period of the study. Therefore, literature review of DEA model and MPI model showed outstanding technique is appropriate and useful method for measuring the productivity change over time.

2. Methodology

2.1 Research Model

2.1.1 DEA Model

DEA method is a popular tool and most commonly used to analyze the performance of various aspects of research in agricultural economics (Barros & Leach, 2006; J. S. Liu, Lu, Lu, & Lin, 2013). Several studies have demonstrated that DEA applications involve a wide range of contexts such as education (Fuentes, Fuster, & Lillo-Bañuls, 2016; Lee & Worthington, 2016), banking (Sahin, Gokdemir, & Ozturk, 2016; Tsolas & Charles, 2015) and agriculture (KOČIŠOVÁ, 2015; Shrestha, Huang, Gautam, & Johnson, 2016). Therefore, this study deployed the DEA to calculate the efficiency of the rubber production in southern Thailand. DEA is a non-parametric methodology developed by Charnes, Cooper, and Rhodes (1978) and is based on the assumption of CRS. The advantage of the DEA is it allows researchers to evaluate the performance of each DMU taking into account only the observed quantities of marketable input and output variables and does not require the assumption of functional form relating input to output variables (Picazo-Tadeo, Gómez-Limón, & Reig-Martínez, 2011). In this study, we analyzed using a model based on CCR model and developed by Charnes et al. (1978). It is appropriate when it operates at optimum levels (Huguenin, 2015) and be easily applied in various fields. This study selects n (n = 14 cities) as the DMU to evaluate the efficiency of rubber production in southern part of Thailand. Thus, we use a different input and can produce a different output for each DMU. In this study, TE estimator is measured through DEA input oriented approach under CRS model. The input oriented CCR model was considered in this study which in a form of linear program (Charnes et al., 1978) for computing the technical efficiencies is given in equation (1).

$$\text{Maximize}_{\theta} = \sum_{r=1}^{s} \mu_r y_{rj} \qquad (1)$$

Subject to

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0$$

$$\sum_{i=1}^{m} v_i x_{ij} = 1 \qquad \text{for all } j = 1, 2, \ldots, k$$

$$\mu_r \geq 0 \qquad \text{for all } r = 1, 2, \ldots, n$$

$$v_i \geq 0 \qquad \text{for all } i = 1, 2, \ldots, m$$

Where θ = technical efficiency, y = output, x = input, u and v = weights assigned to output and input respectively, r and i = number of outputs (r = 1, 2, …, n) and inputs (i = 1, 2, …, m) respectively and j = jth DMU under evaluation (j = 1, 2, …, k). The TE scores are ranked from 0 (lowest score = inefficient) to 1 (highest score = efficient).

2.1.2 Malmquist Productivity Index (MPI) Model

MPI was introduced as a theoretical index by Caves, Christensen, and Diewert (1982) and popularized as an empirical index by Fare, Grosskopf, Norris, and Zhang (1994). We calculate MPI by the performance of each DMU at different periods using the technology of a base period. Fare et al. (1994) stated that a distance function in input–oriented MPI's approach can effectively measure the productivity change of a given DMUs between time t and t+1 as shown in Equation (2):

$$M(y^{t+1}, x^{t+1}, y^t, x^t) = \left[\left(\frac{D_i^t(x^{t+1}, y^{t+1})}{D_i^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_i^t(x^t, y^t)}{D_i^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \times \frac{D_i^{t+1}(x^{t+1}, y^{t+1})}{D_i^t(x^t, y^t)} \qquad (2)$$

$$M = TC \times EC$$

Available Online at: http://grdspublishing.org/journals-PEOPLE-home

If M > 1 denotes productivity growth; M = 1 means no change in productivity from period *t* to *t*+1 and M < 1 indicates productivity decline. EC > 1 shows the increase of rubber production efficiency from the time period *t* to the time period *t* + 1; EC = 1 means the rubber production efficiency remains stable during the period *t* to the time period *t* + 1 and EC < 1 indicates the decrease of rubber production efficiency. TC > 1 shows there is an advance in technology; TC = 1 means there is unchanged technology and TC < 1 indicates a deteriorating technology.

2.2 Data Collection and Variables

Data were collected by using secondary data form a survey by a government agency of Thailand: Office of Agricultural Economics of Thailand, Office of the Rubber Replanting Aid Fund, Rubber Research Institute of Thailand and Thai Meteorological Department of Thailand. We analyzed the rubber production from 2007 to 2016 and estimated the TE of rubber productivity with 14 DMUs in southern region of Thailand. This study analyzed a total of five inputs and one output, namely plantation area (X_1), tapping area (X_2), fertilizer (X_3), labor force (X_4), number of tractors (X_5) and rubber quantity (Y). Data analysis was conducted using DEAP Version 2.1 and EViews program Version 8.0.

As presented in Table 1, the descriptive statistics showed average plantation area was quite big hectare (309,290 hectare) and tapping area (182,741 hectare), which indicated that over half of the arable land can produce rubber. The average of fertilizer was 30,979 tons, labor force was 580,290 persons/hour and number of tractors was 7,902 per area per number of tractors. Moreover, an average of rubber quantity shows a very high number at 357,957 tons with the maximum quantity of 968,920 tons and the minimum quantity of 14,939 tons.

Global Research & Development Services

Table 1: *Descriptive statistics of the data*

Variable	Unit	Mean	Standard deviation	Maximum	Minimum
Input					
Plantation area (X_1)	hectare	309,290	75,053	681,337	10,384
Tapping area (X_2)	hectare	182,741	209,505	411,445	29,757
Fertilizer (X_3)	tons	30,979	19,302	139,920	470
Labor force (X_4)	persons/hour	580,290	416,400	25,892	4,082
Number of tractors (X_5)	per area per number of tractors	7,902	10,902	109,593	1,522
Output					
Rubber quantity (Y)	tons	357,957	567,256	968,920	14,939

3. Results and Discussion

3.1 Outcome of DEA model

We analyzed using DEAP 2.1 software to measure the performance of the rubber production in 14 cities of Southern Thailand. As shown in Table 2, we found that the calculated average TE of rubber production from 2007 to 2016 was 0.856, the standard deviation (SD) was 0.087, the maximum TE was 0.939 and the minimum TE was 0.598.

In 2007, we find that the four cities (Suratthani, Trang, Satun and Yala) have TE score equal 1.000 and ten cities (Chumphon, Ranong, Phangnga, Phuket, Krabi, Nakhon-Si-Thammarat, Phatthalung, Songkhla, Pattani, Narathiwat) have TE score less than 1.000.

The results show that in 2008 the five cities (Ranong, Phangnga, Nakhon-Si-Thammarat, Phatthalung and Songkhla) have TE score equal 1.000 and nine cities (Chumphon, Suratthani, Phuket, Krabi, Trang, Satun, Pattani, Yala and Narathiwat) have TE score less than 1.000.

In 2009, we show that the four cities (Phangnga, Trang, Songkhla and Yala) have TE score equal 1.000 and ten cities (Chumphon, Ranong, Suratthani, Phuket, Krabi, Nakhon-Si-Thammarat, Phatthalung, Satun, Pattani and Narathiwat) have TE score less than 1.000.

The study concluded that the three cities (Chumphon, Nakhon-Si-Thammarat and Satun) have TE score equal 1.000 and eleven cities (Ranong, Suratthani, Phangnga, Phuket, Krabi, Trang, Phatthalung, Songkhla, Pattani, Yala and Narathiwat) have TE score less than 1.000 in 2010.

The results of the rubber production in 2011 are shown that the five cities (Suratthani, Krabi, Nakhon-Si-Thammarat, Phatthalung and Narathiwat) have TE score equal 1.000 and nine cities (Chumphon, Ranong, Phangnga, Phuket, Trang, Songkhla, Satun, Pattani and Yala) have TE score less than 1.000.

Chumphon, Songkhla and Pattani have TE score equal 1.000 in 2012. Moreover, Ranong, Suratthani, Phangnga, Phuket, Krabi, Trang, Nakhon-Si-Thammarat, Phatthalung, Satun, Yala and Narathiwat have TE score less than 1.000.

The rubber production in 2013, only two cities (Phatthalung and Narathiwat) have TE score equal 1.000 and twelve cities (Chumphon, Ranong, Suratthani, Phangnga, Phuket, Krabi, Trang, Nakhon-Si-Thammarat, Songkhla, Satun, Pattani and Yala) have TE score less than 1.000.

In 2014, the results show that the four cities (Trang, Nakhon-Si-Thammarat, Songkhla and Yala) have TE score equal 1.000 and ten cities (Chumphon, Ranong, Suratthani, Phangnga, Phuket, Krabi, Phatthalung, Satun, Pattani and Narathiwat) have TE score less than 1.000.

In 2015, the results show that all of the cities have TE score less than 1.000. Finally, in 2016 we find that the four cities (Suratthani, Phangnga, Trang and Yala) have TE score equal 1.000 and ten cities (Chumphon, Ranong, Phuket, Krabi, Nakhon-Si-Thammarat, Phatthalung, Songkhla, Satun, Pattani and Narathiwat) have TE score less than 1.000. Thus, we can conclude that Trang city had higher efficiency scores when compared to other cities, followed by Nakhon-Si-Thammarat, Songkhla, Suratthani, Phatthalung, Yala, Satun, Pattani, Narathiwat, Phangnga, Chumphon, Ranong, Krabi and Phuket.

PEOPLE: International Journal of Social Sciences
ISSN 2454-5899

Global Research & Development Services

Table 2: *Outcome of the DEA model*

Region	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
Chumphon	0.849	0.792	0.984	1.000	0.804	1.000	0.741	0.682	0.621	0.730	0.820
Ranong	0.790	1.000	0.892	0.692	0.799	0.694	0.743	0.802	0.913	0.879	0.820
Suratthani	1.000	0.803	0.863	0.931	1.000	0.830	0.859	0.980	0.873	1.000	0.914
Phangnga	0.890	1.000	1.000	0.794	0.879	0.751	0.681	0.648	0.799	1.000	0.844
Phuket	0.682	0.589	0.691	0.513	0.491	0.581	0.661	0.700	0.581	0.489	0.598
Krabi	0.793	0.789	0.890	0.980	1.000	0.712	0.699	0.679	0.708	0.798	0.805
Trang	1.000	0.904	1.000	0.989	0.869	0.790	0.890	1.000	0.948	1.000	0.939
Nakhon-Si-Thammarat	0.876	1.000	0.983	1.000	1.000	0.879	0.898	1.000	0.901	0.830	0.937
Phatthalung	0.800	1.000	0.902	0.963	1.000	0.877	1.000	0.793	0.830	0.890	0.906
Songkhla	0.942	1.000	1.000	0.914	0.879	1.000	0.832	1.000	0.983	0.809	0.936
Satun	1.000	0.897	0.910	1.000	0.878	0.757	0.869	0.799	0.711	0.795	0.862
Pattani	0.800	0.982	0.813	0.793	0.891	1.000	0.931	0.830	0.732	0.782	0.855
Yala	1.000	0.981	1.000	0.831	0.789	0.698	0.790	1.000	0.890	1.000	0.898
Narathiwat	0.803	0.799	0.792	0.802	1.000	0.961	1.000	0.831	0.790	0.742	0.852
Mean	0.873	0.895	0.909	0.872	0.877	0.824	0.828	0.839	0.806	0.839	0.856
SD	0.102	0.125	0.095	0.144	0.137	0.134	0.112	0.134	0.122	0.141	0.087
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.939
Minimum	0.682	0.589	0.691	0.513	0.491	0.581	0.661	0.648	0.581	0.489	0.598

3.2 Outcome of MPI model

In this study we used the MPI approach to measure productivity changes of rubber production from 2007 to 2016 in Southern Thailand. We used the EViews program Version 8.0 to analyze these data. Table 3 presents average estimates of Malmquist indices of TFP decomposed into TC and EC in Thai rubber production. If the value of TFP is greater than one, it indicates productivity growth as well; less than one implies productivity decline, and equal to one means no change in productivity growth. Therefore, total average including TC was 1.031,

Available Online at: http://grdspublishing.org/journals-PEOPLE-home

EC was 0.979 and TFP was 1.009; thus, we find that productivity of rubber production has improved in the studied period, 2007-2016, as suggested by the Malmquist TFP of rubber production and the value of TFP. The rubber production in southern region had a positive productivity trend in 2009-2010, 2010-2011, 2011-2012, 2013-2014, 2014-2015 and 2015-2016 and had a negative productivity trend in 2007-2008, 2008-2009 and 2012-2013. Furthermore, an overview of studies found that rubber production in southern Thailand has improved in technical efficiency, technology and productivity growth during the period of this study.

Table 3: *Outcome of the MPI model*

Years	**TC**	**EC**	**TFP**	**Estimates of the productivity trend**
2007-2008	1.006	0.973	0.978	decreasing
2008-2009	1.019	0.870	0.886	decreasing
2009-2010	0.993	1.087	1.079	increasing
2010-2011	1.054	0.972	1.025	increasing
2011-2012	1.070	0.974	1.042	increasing
2012-2013	1.004	0.981	0.985	decreasing
2013-2014	1.057	0.987	1.043	increasing
2014-2015	1.070	0.974	1.042	increasing
2015-2016	1.010	0.992	1.002	increasing
Total Mean	1.031	0.979	1.009	increasing

4. Conclusions and Implications

In this study, the production inputs and outputs data from 14 cities in southern Thailand were subjected to DEA model and MPI model to measure efficiency of production and to assess the trend in rubber production over a ten-year period. These methods allow decision-making best practices and also can provide insight that is useful for managing the production of rubber. The empirical results showed that Trang city had higher efficiency scores when compared to other cities, therefore, Trang city was the most effective and suitable for the production of rubber. In contrast, Phuket city has inefficient performance efficiency. Phuket is a tourist town and due to the limited space, making it unfit for cultivation. In addition, an overview of rubber production in southern Thailand revealed quite good performance, however, the rubber production must still be improved to develop production techniques and to maintain production standards. Hopefully, its technical efficiency score could reach the highest efficiency at 1.000 in the nearest future. Moreover, Malmquist index of rubber production was likely to rise due to the increasing trends found in both the TC and the EC of the production.

This study suggested that the Thai government really needs to improve productivity and technical efficiency of rubber production. The rubber yields can be increased by improving innovation technologies; such as, new plant types, new manufacturing technology and new machines. In terms of policies implication, the relevant parties, the farmers, rubber research institutes and Thai government should highly cooperation and integration among the groups. For example, the government and rubber research institutes should provide the knowledge, management skills and correct production skills for farmers. The rubber research institutes should stay in the forefront to increase the rubber yields and raise funds to the farmers for increase sustainable rubber production.

REFERENCES

Barros, C. P., & Leach, S. (2006). Performance Evaluation of the English Premier Football League with Data Envelopment Analysis. Applied Economics, 38(12), 1449-1458.

Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers. The Economic Journal, 73-86.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. European Journal of Operational Research, 2(6), 429-444.

Chauhan, N. S., Mohapatra, P. K., & Pandey, K. P. (2006). Improving Energy Productivity in Paddy Production through Benchmarking-An Application of Data Envelopment Analysis. Energy Conversion and Management, 47(9), 1063-1085.

De Koeijer, T., Wossink, G., Struik, P., & Renkema, J. (2002). Measuring Agricultural Sustainability in Terms of Efficiency: The Case of Dutch Sugar Beet Growers. Journal of Environmental Management, 66(1), 9-17.

Fare, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries. American Economic Review, 84(1), 66-83.

Fuentes, R., Fuster, B., & Lillo-Bañuls, A. (2016). A Three-Stage DEA Model to Evaluate Learning-Teaching Technical Efficiency: Key Performance Indicators and Contextual Variables. Expert Systems with Applications, 48, 89-99.

Huguenin, J.-M. (2015). Data Envelopment Analysis and Non-Discretionary Inputs: How to Select the Most Suitable Model Using Multi-Criteria Decision Analysis. Expert Systems with Applications, 42(5), 2570-2581.

KOČIŠOVÁ, K. (2015). Application of the DEA on the Measurement of Efficiency in the EU Countries. Agric. Econ.–Czech, 61, 51-62.

Kumarasinghe, H., & Patalee, J. C. E. M. B. (2012). Role of Human Capital in Efficiency Increases: Evidence from a Data Envelopment Analysis of Rubber Smallholdings in Gampaha District. Journal of the Rubber Research Institute of Sri Lanka, 92, 12-21.

Lee, B. L., & Worthington, A. C. (2016). A Network DEA Quantity and Quality-Orientated Production Model: An Application to Australian University Research Services. Omega, 60, 26-33.

Liu, J. S., Lu, L. Y., Lu, W.-M., & Lin, B. J. (2013). Data Envelopment Analysis 1978–2010: A Citation-Based Literature Survey. Omega, 41(1), 3-15.

Liu, Y., Mu, C., Jiang, K., Zhao, J., Li, Y., Zhang, L., . . . Ma, T. (2015). A Tetraphenylethylene Core-Based 3D Structure Small Molecular Acceptor Enabling Efficient Non-Fullerene Organic Solar Cells. Advanced Materials, 27(6), 1015-1020.

Longpichai, O., Perret, S. R., & Shivakoti, G. P. (2012). Role of Livelihood Capital in Shaping the Farming Strategies and Outcomes of Smallholder Rubber Producers in Southern Thailand. Outlook on Agriculture, 41(2), 117-124.

Mustapha, N. H. N. (2011). Technical Efficiency for Rubber Smallholders under RISDA's Supervisory System Using Stochastic Frontier Analysis. Journal of Sustainability Science and Management, 6(1), 156-168.

Nomikos, N. K., & Pouliasis, P. K. (2011). Forecasting Petroleum Futures Markets Volatility: the Role of Regimes and Market Conditions. Energy Economics, 33(2), 321-337.

Picazo-Tadeo, A. J., Gómez-Limón, J. A., & Reig-Martínez, E. (2011). Assessing Farming Eco-Efficiency: A Data Envelopment Analysis Approach. Journal of Environmental Management, 92(4), 1154-1164.

Rubber Research Institute of Thailand (RRIT), 2016 Thai Rubber Statistics. Ministry of Agriculture and Cooperative, Bangkok, Thailand. Available at http://www.thainr.com/en/index.php?detail=stat-thai (accessed October 2016).

Sahin, G., Gokdemir, L., & Ozturk, D. (2016). Global Crisis and its Effect on Turkish Banking Sector: A Study with Data Envelopment Analysis. Procedia Economics and Finance, 38, 38-48.

Shrestha, R. B., Huang, W.-C., Gautam, S., & Johnson, T. G. (2016). Efficiency of Small Scale Vegetable Farms: Policy Implications for the Rural Poverty Reduction in Nepal. Agricultural Economics (Zemedelská Ekonomika), 62(4), 181-195.

Singh, G., Singh, S., & Singh, J. (2004). Optimization of Energy Inputs for Wheat Crop in Punjab. Energy Conversion and Management, 45(3), 453-465.

Tsolas, I. E., & Charles, V. (2015). Incorporating Risk into Bank Efficiency: A Satisficing DEA Approach to Assess the Greek Banking Crisis. Expert Systems with Applications, 42(7), 3491-3500.

Xue, X., Shen, Q., Wang, Y., & Lu, J. (2008). Measuring the Productivity of the Construction Industry in China by Using DEA-Based Malmquist Productivity Indices. Journal of Construction Engineering and Management, 134(1), 64-71.