Pilot study of Environmental Accounting in Construction Industry: a case study of Environmental and Economics Key Performance Indicators

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Abstract

Environmental accounting can be considered either a subset or superset of accounting proper, because it aims to incorporate both economic and environmental information. It can be broken down in to three disciplines: Global Environmental Accounting (E.A.), National E.A. and Corporate E.A. (Odum 1996; Jasch, C. 2006). There is a vacancy of investigation E.A. at the industry level. This paper attempts to fill in this gap by examining the environmental accounting in the construction industry with respects to the Economics Key Performance Indicators (KPI) and Environmental KPI relationships. Due to the data availability, the UK construction is selected in present study. Economics Key Performance Indicators (KPI) and Environmental KPI of UK's construction industry from 2003 to 2007 are analyzed. The present study aims to make the intertwined relationship of Environmental and Economics Key Performance Indicators lucid in the construction industry. With simple linearity assumptions, the author developed easily solvable mathematical programs. With the possible explanations for patterns of Environmental and Economics Key Performance Indicators, this study conducts the interviews in the construction industry professionals in Japan and China for their suggestions for validation of the lessons learned from the UK's construction industry. Adopting two complimentary research methods, published data analysis of construction industry of UK and professionals interviews in Japan and China, the author admits the inconsistency of two different country's data source which might exist in this study as the limitation. The furthermore study is recommend to conduct within the compatible context, for instance, one country.

Introduction

Environment is becoming more and more important these days. It is vital to supporting life, absorbing waste and providing inputs for production. In the construction industry, the sustainable construction topics gain more attentions in the academic and professional areas. There is a vacancy of investigation E.A. at the industry level. The present study aims to make the intertwined relationship of Environmental and Economics Key Performance Indicators lucid in the construction industry. Firstly, the author consults the literature regarding the relationships of environmental and economical KPIs in the construction industry. Present study extracted the economical and environmental KPIs from 2003 to 2007 from the UK construction statistical Yearbook. And two stage data analysis has been done to generate the quantitative models for the environmental and economical KPIs and last section is to use the Japanese and Chinese experts' knowledge to qualitatively validate the findings.

Literature review

Since the 1960s, there has been increasing concern about the effects of economic activity in environment (Thirlwall, 2003). World Development Report 1992 shows how selected environmental indicators, urban concentration of sulphur dioxide, carbon dioxide emission per capita etc., vary with economical indicator, as measured by per capita income(World Bank, 1992). Apart from those generic indicators, literature lacks of the consensus for environmental and economical indicators at the industry level. In construction industry, UK published the annual statistical yearbook for the economical and environmental KPIs. Present study intends to adopt those indicators for the preliminary study in the environmental economics area in construction industry.

The market-based approach to environmental analysis has probably been the dominant view of the relationship between the environment and the economy (Common, 1996). The market or neoclassical approach to economics is concerned with how scare resources are allocated in a market economy. For example, the building and operation of the hydroelectric dams, these dams generate cheap electricity which is distributed to the countries. Downstream from the dams, the annual floods have been reduced and this has decreased agricultural productivity. Additionally, the elimination of salt water intrusion through the building of these dams has led to an increased incidence of bilharzias and other health problems. Their relationships can be shown in the following diagram: the downstream environmental degradation by the generators produces a benefit to them as it allows the production of electricity. This is denoted by the marginal benefit curve MB (measured in dollars) and is assumed to be downward sloping. The downward slope can be justified by a lower price being obtained for the sale of electricity as more is produced. The environmental effects are mostly negative and are represented by an upward sloping marginal cost of environmental degradation curve (MC).

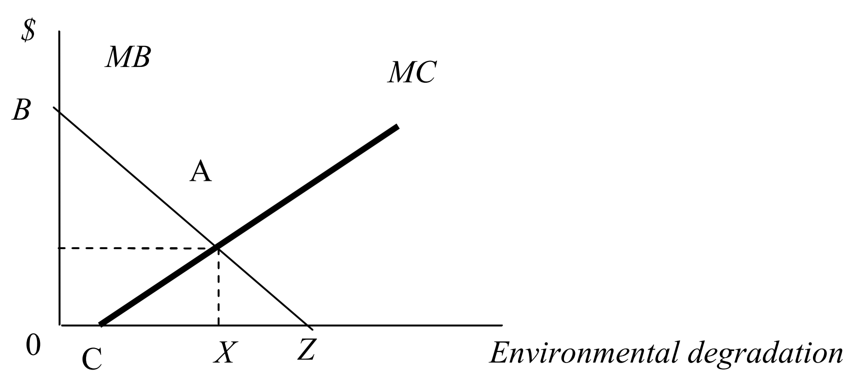

Figure 1.1 Marginal benefits and environmental cost of dams
(Source: Common, 1996)

However, the market approach is assumed that market function efficiently with regard to the environment. But sometime the market failure would cause the model not applicable and additionally the unavailability of the accurate data makes this approach even more difficult to adopt.

In construction industry, the researches regarding the economical and environmental KPIs are still a novel research arena. Igal's study used a systematic field survey followed by an in-depth statistical analysis to examine the efficiency of maintenance under alternative maintenance policies and alternative sources of labour (outsourcing vs. in-house) on maintenance of hospital buildings as a model for multi-system buildings operating in dynamic environments (Igal et.al, 2003). The proposed KPIs integrate four aspects of hospital facilities management: performance management, composition of labour, efficiency of maintenance operations and organizational effectiveness. However, the research does not focus on the investigations of environmental and economics KPIs at industry level.

Present study extracted the economical and environmental KPIs form 2003 to 2007 from the UK construction statistical Yearbook to seek the possibility of research in the industrial level. Economics KPIs are encompassed of: Client Satisfaction – Product, Client Satisfaction – Service, Defects, Safety, Cost Predictability (Project, Design, and Construction), Time Predictability (Project, Design, and Construction), Profitability, Productivity, Cost, and Time. Environmental KPIs includes Impact on the Environment – Design & Construction Process, Energy Use (Designed) – Product, Energy Use – Construction Process, Mains Water Use (Designed) – Product, Mains water use – Construction Process, Waste – Construction Process, Commercial Vehicle Movements – Construction Process, Impact on Biodiversity – Product & Construction Process, Area of Habitat Created –/Retained – Product, Whole Life Performance – Product.

Data Analysis

Dichotomous data analysis was adopted in current study: first stage is Pearson correlation analysis for the environmental and economical KPIs; second stage is use the optimization technique to capture the parameters which signified their relationships.

The Pearson correlation coefficient is adopted to examine the linear associations between economical and environmental KPIs. SPSS® assists the data analysis, for example, Client Satisfaction – Product is significant correlated with Impact on the Environment – Design and the following diagram presented the relationship. In addition, the plot between these two variables was used to give a visual depict of the relationships between them.

Correlations

		Client_Sat_Prdt	Impact_Envi_Dsgn
Client_Sat_Prdt	Pearson Correlation	1	.958(*)
	Sig. (2-tailed)	.	.010
	N	5	5
Impact_Envi_Dsgn	Pearson Correlation	.958(*)	1
	Sig. (2-tailed)	.010	.
	N	5	5

* Correlation is significant at the 0.05 level (2-tailed).

Figure 1.2 Pearson Correlation coefficient Client Satisfaction – Product and Impact on the Environment – Design (source: author)

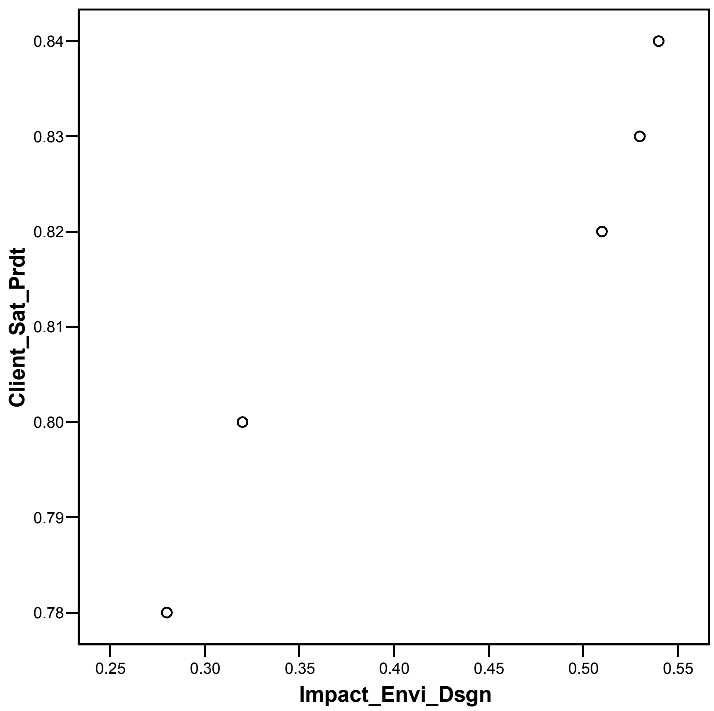

Figure 1.3 Plot the relationships of Client Satisfaction – Product and Impact on the Environment – Design (source: author)

After conduct the Pearson correlation of all the economical and environmental KPIs, only the economical and environmental KPIs which are significantly correlated are extracted for the further data analysis. They are Client Satisfaction – Product, Client Satisfaction – Service, Defects, Safety, Cost Predictability (Project), Cost Predictability (Construction), Time Predictability (Project), Time Predictability (Design), Time Predictability (Construction), Profitability, Productivity, and Cost. Environmental KPIs includes Impact on the Environment – Design & Construction Process, Energy Use

(Designed) – Product, Mains Water Use (Designed) – Product, Mains water use – Construction Process, Commercial Vehicle Movements -Construction Process, Impact on Biodiversity – Product & Construction Process, Whole Life Performance – Product. The full set of correlation coefficient, 12×7 matrix, could not be shown in the limited page of the Word® document therefore the following diagram shows only few economical and environmental KPIs correlation coefficients to elaborate the rationale to select the significantly correlated economical and environmental KPIs.

		Impact_Envi_Dsgn	Impact_Env_Conproc	Eng_Used_Dsgn
Client_Sat_Prdt	Pearson Correlation	.958*	-.739	-.706
	Sig. (2-tailed)	.010	.154	.183
	N	5	5	5
Client_Sat_Svc	Pearson Correlation	.883*	-.618	-.652
	Sig. (2-tailed)	.047	.267	.233
	N	5	5	5
Dfts	Pearson Correlation	.887*	-.780	-.864
	Sig. (2-tailed)	.045	.120	.059
	N	5	5	5
Sft_all	Pearson Correlation	-.856	.889*	.864
	Sig. (2-tailed)	.064	.044	.059
	N	5	5	5
Sft_Ctrct	Pearson Correlation	.807	-.772	-.800
	Sig. (2-tailed)	.099	.127	.104
	N	5	5	5
Prdt_cost_Construction	Pearson Correlation	-.749	.455	.702
	Sig. (2-tailed)	.145	.441	.187
	N	5	5	5
Prdt_cost_Prjt	Pearson Correlation	-.916*	.736	.922*
	Sig. (2-tailed)	.029	.156	.026
	N	5	5	5
Prdt_time_Dsgn	Pearson Correlation	.360	-.220	-.887*
	Sig. (2-tailed)	.552	.722	.045
	N	5	5	5
Prdt_time_Construction	Pearson Correlation	.596	-.608	-.507
	Sig. (2-tailed)	.289	.277	.383
	N	5	5	5
Prdt_time_Prjt	Pearson Correlation	.400	-.491	-.531
	Sig. (2-tailed)	.505	.401	.357
	N	5	5	5
Profitablity	Pearson Correlation	.909*	-.666	-.672
	Sig. (2-tailed)	.032	.219	.214
	N	5	5	5

Fig 1.4 Pearson Correlation coefficient of selected economical and environmental KPIs (source: author)

The second stage: After extracted significantly correlated economical and environmental KPIs, the next step is to establish their relationship parameters. In view of the small data set here, this study adopts the Excel Solver to derive the attributes of the relationships between the economical and environmental KPIs. Using Client Satisfaction – Product (Client_Sat_Prdt) as an example, the environmental KPIs which are significantly correlated with it are Impact on the Environment – Design & Construction Process (Impact_Envi_Dsgn), Commercial Vehicle Movements -Construction Process (Vh_Mv_Conproc), Impact on Biodiversity – Product & Construction Process (Impc_Biodiversity_Conprcss) , Whole Life Performance – Product(WL_Pfmc). Firstly, we assume the linear relationship between the Economical KPIs and Environmental KPIs:

$$\text{Client\_Sat\_Prdt} = \partial_1 \text{Impact\_Envi\_Dsgn} + \partial_2 \text{Vh\_Mv\_Conproc} + \partial_3 \text{Impc\_Biodiversity\_Conprcss} + \partial_4 \text{WL\_Pfmc}$$

here, $\partial_{1,2,3,4}$ are the parameter to express their relationships.

This study employed the Generalized Reduced Gradient (GRG2) nonlinear optimization to calculate the weights of the attribute. GRG 2 was developed by Leon Lasdon, University of Texas at Austin, and Allan Waren, Cleveland State University. In order to use GRG2 to generate weights. The Solver optimization screen is shown in Fig. 1.5 with the adjustable cells containing the optimization variables. In this study, the range of the attribute weights was set between 0 and 1, the iteration was set to 100. The precision was set to 10^{-6} . The tolerance is 5%, the convergence is 10^{-4} and Solver was run 100 times to find the optimum attribute.

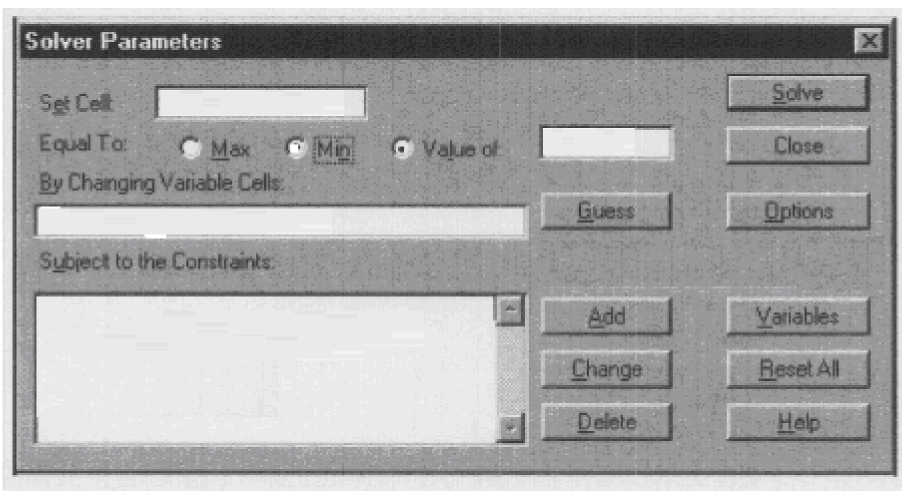

Fig. 1.5 Microsoft Solver optimization screen (source: author)

In this case, the environmental KPIs and economical KPIs in UK annual year book of construction industry from 2003 to 2007 are extracted for this study. Five sets of data was used to derive the weights between the environmental and economical KPIs, the solution is the one which has the highest accuracy, the lowest error rate.

Percentage error (PE) = (Predicted value− actual value)/Actual value× 100%

For Client Satisfaction – Product (Client_Sat_Prdt), the weights derived from 2007 data set are used here due to its lowest error rate, 13.65%. And because the weight of

Commercial Vehicle Movements -Construction Process (Vh_Mv_Conproc) is zero, this factor was thus excluded in the following equation to signify their relationships.

Client_Sat_Prdt = 0.59Impact_Envi_Dsgn + 0.56Impc_Biodiversity_Conprcss + 0.62WL_Pfmc

The detail derivation process is simply showed in the spreadsheets as following. The leftover eleven economical KPIs quantitative relationships with the environmental KPIs were summarized in the following equations:

Client_Sat_Svc = 0.50Impact_Envi_Dsgn + 0.57Impc_Biodiversity_Conprcss + 0.61WL_Pfmc

Dfts = 0.74Impc_Biodiversity_Conprcss + 0.01Waste

Sft_all = 24.58Impc_Biodiversity_Conprcss + 1.28Waste

Prdt_cost_Dsgn = 0.78Impc_Biodiversity_Prdc + 0.59Impact_Envi_Dsgn

Prdt_cost_prjt = 0.35Impact_Envi_Dsgn + 0.29Impc_Biodiversity_Conprcss + 0.4WL_Pfmc

Prdt_time_Dsgn = 0.0001Eng_Used_Dsgn

Profitablity = 0.10Impact_Envi_Dsgn + 0.074WL_Pfmc

Productivity_Cur_Value = 0.008Eng_Used_Dsgn

Cons_Cost = -0.003Vh_Mv_Conproc

Raw Data

Client_Sat_Prdt	Impact_Envi_Dsgn	Vh_Mv_Conproc	Impc_Biodiversity_Conprcss	WL_Pfmc			
0.78	0.28	44	0.35	0.29			
0.8	0.32	34.5	0.39	0.35			
0.83	0.53	29.4	0.45	0.41			
0.84	0.54	30.4	0.48	0.41			
0.82	0.51	29.4	0.46	0.39			
			Data Analysis				
	Client_Sat_Prdt	Impact_Envi_Dsgn	Vh_Mv_Conproc	Impc_Biodiversity_Conprcss	WL_Pfmc		
		0.8624561	0	0.82807018	0.857544	Abs.value ofAccumulated error	Error Rate
0.78	0.78	0.28	44	0.35	0.29	1.5E-14	
0.899074	0.8	0.32	34.5	0.39	0.35	0.09907	
1.181326	0.83	0.53	29.4	0.45	0.41	0.35133	
1.214793	0.84	0.54	30.4	0.48	0.41	0.37479	
1.155207	0.82	0.51	29.4	0.46	0.39	0.33521	
						1.1604	0.2975
		0.7783609	0	0.72557912	0.765565		
0.693908	0.78	0.28	44	0.35	0.29	0.08609	
0.799999	0.8	0.32	34.5	0.39	0.35	1E-06	
1.052923	0.83	0.53	29.4	0.45	0.41	0.22292	
1.082474	0.84	0.54	30.4	0.48	0.41	0.24247	
1.029301	0.82	0.51	29.4	0.46	0.39	0.2093	
						0.76079	0.2192

		0.5970111	0	0.57160285	0.625275		
0.548554	0.78	0.28	44	0.35	0.29	0.23145	
0.632815	0.8	0.32	34.5	0.39	0.35	0.16719	
0.83	0.83	0.53	29.4	0.45	0.41	3.4E-14	
0.853118	0.84	0.54	30.4	0.48	0.41	0.01312	
0.81127	0.82	0.51	29.4	0.46	0.39	0.00873	
						0.42048	0.1533
		0.5867462	0	0.56247847	0.617481		
0.540226	0.78	0.28	44	0.35	0.29	0.23977	
0.623244	0.8	0.32	34.5	0.39	0.35	0.17676	
0.817258	0.83	0.53	29.4	0.45	0.41	0.01274	
0.84	0.84	0.54	30.4	0.48	0.41	7.2E-15	
0.798798	0.82	0.51	29.4	0.46	0.39	0.0212	
						0.45047	0.1667
		0.5867587	0.0007207	0.56248975	0.617491		
0.571945	0.78	0.28	44	0.35	0.29	0.20805	
0.648118	0.8	0.32	34.5	0.39	0.35	0.15188	
0.838461	0.83	0.53	29.4	0.45	0.41	0.00846	
0.861924	0.84	0.54	30.4	0.48	0.41	0.02192	
0.820001	0.82	0.51	29.4	0.46	0.39	1E-06	
						0.39032	0.1364

Tab. 1.1 The weights derivation process, source: author.

Results and discussion

The verbal description of the results are: there are three environmental KPIs which are significantly correlated to Client Satisfaction – Product (Client_Sat_Prdt), Impact on the Environment – Design & Construction Process (Impact_Envi_Dsgn), Impact on Biodiversity – Product & Construction Process (Impc_Biodiversity_Conprcss) , Whole Life Performance – Product(WL_Pfmc). Among those factors, Whole Life Performance – Product(WL_Pfmc) has the most significant importance.

For Defects, Impact on Biodiversity – Product & Construction Process and Waste – Construction Process are the critical factors and Impact on Biodiversity – Product & Construction Process is the most important factor.

For Safety, Impact on Biodiversity – Product & Construction Process and Waste – Construction Process are the critical factors and Impact on Biodiversity – Product & Construction Process is the most important factor.

For Cost Predictability (Project), Impact on Biodiversity – Product & Construction Process and Impact on the Environment – Design & Construction Process are the critical factors and Impact on Biodiversity – Product & Construction Process is the most important factor.

For Cost Predictability (Design, and Construction), Impact on Biodiversity – Product & Construction Process and Impact on the Environment – Design & Construction Process and Whole Life Performance – Product are the critical factors, Whole Life Performance – Product has the most critical importance.

For Time Predictability (Project, Design, and Construction) and Productivity, Energy Use (Designed) – Product is the only significant factor.

For Profitability, Impact on the Environment – Design & Construction Process and Whole Life Performance – Product are the critical factors, and Whole Life Performance – Product has the most critical importance.

For Cost, Commercial Vehicle Movements – Construction Process is the only significant factor.

Qualitative validation

The qualitative validation was conducted to use the expert's knowledge to examine the accuracy of the result. Interviews are completed by four experienced professional to validate the finding of this study. The following table is the experts' background information.

Experts' basic information	Details	Expert number	Note: (the nationality and the company of the respondents)
Experienced years in construction industry	< 5year	0	
		0	
	10-20	1	Japan (1) (University Professor)
	> 20	3	China(2) (Construction company CEO and University Professor) Japan(1) (University Professor)
Expertise Area	Consultancy	3	Japan (2) (University Professor)
	Contracting	2	China(2) (Construction company CEO and University Professor)

Fig 1.6 The experts' background information source: author

After consulting the experts, this study summarized the validated research results as following: Mains Water Use (Designed) – Product, Mains water use – Construction Process, these water related factors, are less important environmental factors to economical KPIs. Impact on the Environment – Design & Construction Process, Impact on Biodiversity – Product & Construction Process, Whole Life Performance – Product are important KPIs to economical KPIs.

Future recommendation

Adopting two complimentary research methods, published data analysis of construction industry of UK and professionals interviews in Japan and China, the author admits the inconsistency of two different country's data source which might exist in this study as the limitation. The furthermore study is recommend to conduct within the compatible context, for instance, one country if possible. The future study is recommending examining why water related factors are less important environmental KPIs to economical KPIs in the construction industry. This study classified the KPIs into two groups, environmental and economical. Based on preliminary research finding of this study, future research can investigate the further relationships of them. It will show how to help the construction industry practitioner to have a clear understanding of environmental KPIs to economical KPIs.

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