The 6th International Conference on Construction Engineering and Project Management (ICCEPM 2015)
Oct. 11 (Sun) ~ 14 (Wed) 2015 • Paradise Hotel Busan • Busan, Korea
www.iccepm2015.org

Preliminary Study on Market Risk Prediction Model for International Construction using Fractal Analysis

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Abstract: ***Mega-shock means a sporadic event such as the earning shock, which occurred by sudden market changes, and it can cause serious problems of profit loss of international construction projects. Therefore, the early response and prevention by analyzing and predicting the Mega-shock is critical for successful project delivery. This research is preliminary study to develop a prediction model that supports market condition analysis and Mega-shock forecasting. To avoid disadvantages of classic statistical approaches that assume the market factors are linear and independent and thus have limitations to explain complex interrelationship among a range of international market factors, the research team explored the Fractal Theory that can explain self-similarity and recursiveness of construction market changes. The research first found out correlation of the major market factors by statistically analyzing time-series data. The research then conducted a base of the Fractal analysis to distinguish features of fractal from data. The outcome will have potential to contribute to building up a foundation of the early shock warning system for the strategic international project management.***

Keywords: International Construction Market, Mega-shock, Fractal Theory, Market Factors, Risk Management

I. Introduction

A. Research Background

Many construction companies are trying to enter global construction market (ICAK, 2015). The problem is that market factors in global construction have great degree of variability (He Zhi, 1995; Seung H. Han et al., 2007), so the risk prediction and management is critical in the delivery of the individual projects as well as in the aspect of market continuity (F. H. Griffis and Symeon Christodoulou, 2000; Famad Nasirzadeh et al., 2008). Especially, forecasting the Mega-shock, a sporadic event such as the earning shock occurred by sudden market change, is important to prevent many serious profit loss of global construction projects.

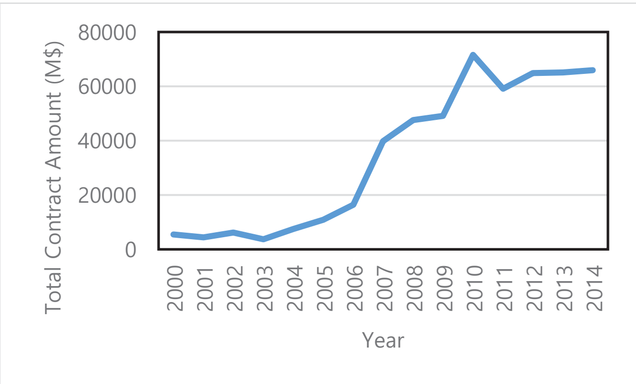

Figure 1 International Contract Amount of Korean Construction (ICAK, 2015)

One of the biggest issues of previous research on global construction market risk was about risk identification and risk assessment (Jamal F. Al-bagar and Keith C. Crandall, 1990; Joshua P. Zilke et al., 2014). However, it needs time-series analysis because market factors fluctuate through time to time. Still, general time-series analysis also has a limitation in that many classical models forecasting financial factors follow Gaussian distribution, hence the models only can show trend not the spark point (Benjamin Topper and Patrick Lagadec, 2013). Of course the trend forecasting is important on financial research, but its result can't make critical contribution on risk management.

To avoid the weakness of classical time-series models, this research follows the assumption that the market factors are non-stationary time-series which means they don't have parameters like mean or variation (Kumar J. and Manchanda P., 2009). The non-stationary time-series factors can be analyzed by Fractal theory (Benjamin Topper and Ptrick Lagadec, 2013) which is a type of analysis based on the fractal, geometric structure with three main characteristics: Self-similarity, recursiveness, and non-parametric.

This research is a preliminary study on development of market risk prediction model for international construction using fractal analysis. The aim of this research is verification of fractality of global construction market factors by using R/S analysis, and suggestion of an analysis frame on high variation factors using Box-width conversion method.

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B. Research Process

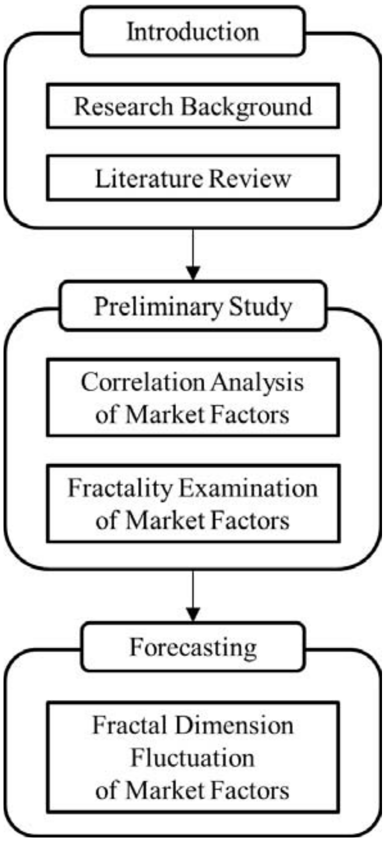

Figure 2 Research Framework

This research firstly found out the major market factors depending on experts' comments and followed the suggestion from the research of Makarand Hastak and Aury Shaked, dividing the international market risk into three levels: Macro, market, and project (Makarand Hastak and Aury Shaked, 2000). After data collection, the research accomplished correlation analysis to remove not-correlated factors which have no reason to be analyzed in further steps. Then R/S analysis was performed to calculate the Hurst exponent of each factors, which represents each factors' fractal dimension. Finally, the research found out the fluctuation of the Hurst exponent on various length of box size using Box-width conversion method. Following table shows the factors used and each methodologies are explained in following section.

Variable Type	Risk Level	Market Factor
Independent Variable	Macro	Crude Oil Price
		Exchange Rate
Dependent Variable	Market Volume	Annual Construction Spending
	Project Profitability	Construction Cost Index

Table 1 Global Market Factors used in the Research

II. METHODOLOGY

A. Correlation Analysis

As mentioned in research process, the research analyzed Pearson correlations of each factors using automatically calculating programs (SPSS and R).

$$r^2 = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 * \sum(y_i - \bar{y})^2}}$$

Equation 1 Pearson Correlation Function

B. Fractal Dimension

Fractal dimension indicates the degree of self-similarity, complexity, and irregularity of the system (Weigen Chen et al., 2012). In geometry science, dimension means degree of covering the whole system A by small N sets of size r, where r is a positive real number (Edgar E. Peters, 1994; Tejas Parasher, 2008). N and r follow the power law, then the power of equation is the dimension of system A.

$$N = c * \left(\frac{1}{r}\right)^D \quad (c: Constant, D: Dimension)$$

Equation 2 General Equation of Dimension

If A is a line, the dimension is 1, so the following equation can be settled.

$$A = N * r, N = A * (\frac{1}{r})^1$$

Equation 3 Power Law of 1-dimension

The dimension can be calculated easily by logarithms and limits.

$$log(N) = log(c) + D * log\left(\frac{1}{r}\right)$$

$$D = \lim_{r \to \infty} \frac{log(N)}{log\left(\frac{1}{r}\right)}$$

Equation 4 Dimension Calculation

This equation can be also used to calculate the dimension of fractal. For one-dimensional data like time-series, equation 2 can be written like equation 6 (Espen A. F. Ihlen, 2012).

$$X(ct) = c^H * X(t)$$

Equation 5 Power Law of Time-series

The fractal dimension of a time-series indicates how the data moves unevenly and makes it possible to predict the point and size of future sporadic event (Edgar E. Peters, 1994; Espen A. F. Ihlen, 2012).

C. R/S Analysis and Hurst Exponent

Because the time-series is not continuous data, it needs another method to calculate the fractal dimension. There are several statistical methods to analyze fractal time-series data such as R/S analysis, autocorrelation, dispersional analysis, wavelet, fourier spectral analysis, box-counting, power spectrum dimension, etc (Schepers et al., 1992; James B. Bassingthwaighte and Gary M. Raymond, 1995; A. Arneodo et al., 2002; R. Gencay et al., 2002; Ashok Razdan, 2004; Kumar J. and Manchanda P., 2009; Weigen Chen et al., 2012). The main objective of this research is not using and evaluating specific methods, but preliminarily study about fractal analysis. Therefore, we start the research with R/S analysis.

R/S analysis is a short name of Rescaled Range Analysis, a robust technique which covers long memory time-series, fractal data, and the presence of cycles. It doesn't have any parameters so it's free from the distribution of data (Edgar E. Peters, 1994). The result of R/S analysis is called Hurst exponent (H) and can be simply conversed to fractal dimension (James B. Bassingthwaighte and Gary M. Raymond, 1995; Kumar J. and Manchanda P., 2009).

$$D = 2 - H$$

Equation 6 The relationship between Fractal Dimension and Hurst Exponent

If 0.5<H≤1.0, it means that the data is persistence process which is same with fractal (Edgar E. Peters, 1994; Espen A. F. Ihlen, 2012; M.J. Sanchez-Granero et al., 2012; Yen-Ching Chang et al., 2014). The relationships between Hurst exponent and process types are summarized in table 2.

Hurst Exponent Value	Process Type	Data Properties
0 ≤ H < 0.5	Anti-persistence Process	Mean-reverting
H = 0.5	Independent Process	Ex) Normal Distribution
0.5 < H ≤ 1.0	Persistence Process	Fractal
1.0 < H	Random Walk	Brown Motion

Table 2 Hurst Exponent Value (Edgar E. Peters, 1994, Fractal Market Analysis, modified)

D. Calculation of Hurst Exponent – R/S Analysis

Let's get an example of Hurst exponent with crude oil price from WTI (West Texas Intermediate). The raw data was collected from Federal Reserve Bank of ST. Louis (http://research.stlouisfed.org/, 2015). The time period is from January 2, 1986 to October 1, 2013, and the total number of entities is 7,001. The process and index are mainly following that of Edgar E. Peters'.

① The raw data is named as time-series 'M'.

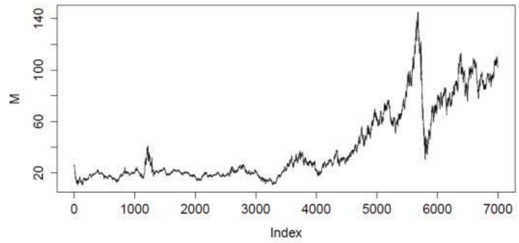

Figure 3 Raw Data M

② Normalize M by logarithmic ratio 'N'.

$$N = log\left(\frac{M_{(i+1)}}{M_i}\right)$$

Equation 7 Logarithmic Ratio N

③ Divide N by 'A' contiguous sub-period of length 'n'. The example used n=20.

$$N = A * n$$

Equation 8 Contiguous Sub-period of N

④ Calculate the average 'e_a' of each sub-period 'I_a'.

$$e_a = \left(\frac{1}{n}\right) * \sum_{k=1}^{n} N_{k,a}$$

Equation 9 Average of each Sub-period (a: 1~A)

⑤ Calculate the accumulated departure $X_{k,a}$ from e_a '$X_{k,a}$'.

$$X_{k,a} = \sum_{i=1}^{k} (N_{i,a} - e_a)$$

Equation 10 Accumulated Departure X

⑥ Calculate the range 'R_{I_a}' and sample standard deviation 'S_{I_a}'.

$$R_{I_a} = max(X_{k,a}) - min(X_{k,a})$$
$$S_{I_a} = \sqrt{\left(\frac{1}{n}\right) * \sum_{k=1}^{n}(N_{k,a} - e_a^2)}$$

Equation 11 Range R and Standard Deviation S

⑦ Calculate the Rescaled Range of each I_a: R_{I_a}/S_{I_a}.

⑧ Calculate the average R/S value at sub-period length n.

$$(R/S)_n = \left(\frac{1}{A}\right) * \sum_{a=1}^{A} \left(R_{I_a} / S_{I_a}\right)$$

Equation 12 R/S Value

⑨ Finally, perform least square regression of $log((R/S)_n)$ and $log(n)$. Then, the slope of the equation is the estimate of Hurst exponent.

For this example, the slope (=H) was estimated as 0.5289 and the p-value was less than $2e^{-16}$. That is, the crude oil price from WTI has fractal features.

E. Box-width Conversion Method

The Box-width conversion method is another widely used method for calculating the fractal dimension and perform fractal analysis (Weigen Chen et al., 2012). The research proceeds the Box-width conversion method in following process. The process and index are mainly following those of Weigen Chen's.

① Calculate total area covered by bow of width r. (Fractal Curve: 'L'; Box Width: 'r'; Number of boxes to cover the curve: 'M'; Total area covered by box: 'S(r)').

$$S(r) = \sum_{i=1}^{M} \{max(L) - min(L)\} * r$$

Equation 13 Total Area Covered by Box

② Calculate number of squares of width r to cover S(r): 'N(r)'.

$$N(r) = \frac{S(r)}{r^2}$$

Equation 14 Number of Squares to Cover S(r)

③ Perform least square regression as in the R/S analysis, and the slope of the curve plotted by $ln\,N(r)$ and $ln\frac{1}{r}$ is the fractal dimension: 'D'.

The calculated fractal dimensions change as the width of box changes. There is a scale-free zone of r, where the fractal dimensions results pretty uniformly. The degree of uniformity should be determined by researcher. The fractal dimension which is calculated only in scale-free zone is significant in the fractal analysis (Weigen Chen et al., 2012).

III. RESULT

A. Result of correlation Analysis

Dependent Variable		Independent Variable	
		Oil Price	
Annual Construction Spending	Country	Coefficient of Correlation	p-value
	USA	0.579	0.003
	AUS	0.954	0.000

Table 3 Coefficient of Correlation_Annual Construction Spending

Table 3 indicates the coefficient of correlation and p-value between the annual crude oil price and the annual construction spending. Each pair showed very high degree of correlation.

Dependent Variable			Independent Variable	
			WTI Oil	Brent Oil
	Country	Sub-category	Coefficient of Correlation	Coefficient of Correlation
Constr. Cost Index	USA	-	0.844	0.811
	AUS	Building	0.915	0.901
		House	0.898	0.891
		Other Residential	0.912	0.891
		Non-residential	0.919	0.899
		Road & Bridge	0.892	0.890
Every p-value < 0.001				

Table 4 Coefficient of Correlation_Construction Cost Index

Table 4 indicates the coefficient of correlation and p-value between the quarterly oil price calculated from daily data and the construction cost index. Each pair showed very high degree of correlation.

B. Result of R/S Analysis – Hurst Exponent

Data			# of Sample	H	p-value
Crude Oil Price			153	0.5958	0.1170
WTI Oil Price			7400	0.5382	0.0013
Brent Oil Price			7091	0.5731	0.0010
Annual Constr. Spending	USA		25	NA	NA
	AUS		25	NA	NA
Constr. Cost Index	USA	-	208	0.9086	NA
	AUS	Building	75	NA	NA
		House	75	NA	NA
		Other Residential	75	NA	NA
		Non-residential	75	NA	NA
		Road & Bridge	71	0.6882	0.0440

Table 5 Hurst Exponent of Factors Used

Table 5 indicated the Hurst exponent of market factors. Every factors except the annual construction spending has the Hurst exponent above 0.5, which means they are kinds of fractal. However, p-values of the construction cost index are not available except road and bridge of Australia, which means the Hurst exponents are not significant.

C. Result of Box-width Conversion Method

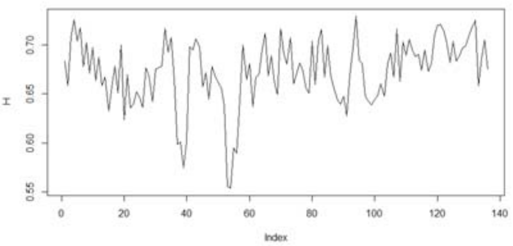

Figure 4 Fractal Dimension of WTI Oil Price

Figure 4 indicates the fluctuation of fractal dimension of WTI oil price when the box width is 200 and the sliding size is 50.

D. Discussion

As preliminary study to develop a global construction market risk prediction model, this research proceeded with some factors selected by experts. Every factors used in the research showed significant correlations, and the independent variable, oil price, has appropriate value of the Hurst exponent that means it has features of fractal.

The reason that other factors showed insignificant results might be because of some characteristics of R/S analysis. Its segments are contiguous and exclusive, so the number of samples in one segment have to be a prime number of whole sample size. The difference came from preprocess on the construction cost index of Australia, being removed some oldest points to make the sample size appropriate number for R/S Analysis, is following.

Data		Non-preprocessed		Preprocessed	
		H	p-value	H	p-value
Constr. Cost Index (AUS)	Building	NA	NA	0.9467	0.0347
	House	NA	NA	0.7344	0.0567
	Other Residential	NA	NA	0.8690	0.0231
	Non-residential	NA	NA	0.9768	0.0407
	Road & Bridge	0.6882	0.0440	0.6882	0.0440

Table 6 Difference came from Preprocess on R/S Analysis

IV. CONCLUSION

A. Contribution

This research find out that global construction market factors have features of fractal by R/S analysis and the Hurst exponent. It represents that those factors have self-similarity, and some sporadic events can be predicted as well as general trend. As mentioned in introduction, prediction of sporadic event is important on global construction markets and individual projects. The situation of this research is pretty insufficient for preliminary study, but it will help the government and companies to predict and response to sporadic shock earlier.

B. Limitation

It needs some data sets that are known to have fractality to validate the source code of R/S analysis and Box-width conversion method. As mentioned in discussion, the methods used in this research are highly affected by sample size.

C. Conclusion

There are many kinds of research that tried to predict market trend. This research concentrated more on sporadic event than trend, which makes difference from other prediction model. The prediction model in the further study would contain more various factors, but this research started with some factors that are easy to be collected and have clear correlation. The factors used in the research were showed to have features of fractal, and that means the fractal theory, which is about predict through self-similarity, can be applied to developing prediction model

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This research is supported by The National Research Foundation of Korea (NRF) throughout a grant by the Korea government (NRF-2013R1A1A2010875)