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Measuring Construction Materials Price Fluctuation Risk

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Abstract: Construction projects costs are believed to be highly susceptible to a combination of internal and external factors. One of these factors is the prices of construction materials and the risk of their fluctuation. This paper explores this risk by statistically measuring the historical volatility of the prices of three key construction materials; namely steel, cement, and lumber. The main objective of this analysis is to assess the degree of risk involving construction materials as a first step in an ongoing research that targets developing means for hedging against the price fluctuation risk.

1 Introduction

The escalation of construction materials prices is often identified as one of the risks that can affect construction projects. Some of the causes that have been attributed to such escalation include inflation, increasing global demand or decreasing supply (as dictated by basic economics), high energy and transportation costs, in addition to the occasional natural disasters (Gallagher and Riggs 2006). Depending on the severity of the escalation and on how this risk is allocated in construction contracts, price escalation can directly lead to the delay or even the cancellation of ongoing projects as well as the over-bidding for new projects by cautious and risk-averse contractors.

The literature provides various recommendations for the mitigation and allocation of the materials price escalation risk (for detailed recommendations please refer to Gallagher and Riggs 2006 and Van der Schans 2005). One recommendation that is frequently present in the literature is the inclusion of a price escalation clause in construction contracts, a clause that "allows for an equitable adjustment for the increased costs of certain materials". Inserting this clause in a construction contract will allow the parties; particularly, the owner and the contractor, to plan, in advance, for the uncertainty and to agree on how and to what extent the additional unanticipated costs will be absorbed and allocated in case materials price increases (Brian R. Gaudet, n.d.). Alternatively, rather than an escalation clause, a fluctuation clause can be used whereby both scenarios of cost increase and decrease are covered under the clause and in that case, either situation (price increase or decrease) can result in an adjustment of the contract price.

Remarkably, price escalation/fluctuation clauses are not a common feature in all widespread standardized construction contracts. One of the popular examples is the construction contract developed by the American Institute of Architects (AIA) (2007), which does not include provisions whatsoever for the adjustment of the contract price due to materials price escalation/fluctuation. On the other hand, escalation/fluctuation clauses can be found, with varying levels of detail, in some other prevalent construction contracts. For example, both Clause 70.1 of the fourth edition of Fédération Internationale Des Ingénieurs-Conseils (FIDIC) Red Book (1987) and Clause 13.8 of the 1999 version of the same contract (1999) provide provisions that can be applied for the adjustment of contractors' prices for rises or falls in the cost of labor, goods, and other inputs to construction works. Similarly, Clause 2 of the ConsensusDocs Coaliation Contract No. 200.1, Amendment No. 1 (2011), requires the parties to agree on a method for establishing the materials baseline price and on a method for "calculating an adjustment in the pricing for a Potentially Time and Price-Impacted Material". It is noteworthy that before the aforementioned amendment, the ConsensusDocs construction contract had no provisions for price adjustment due to escalation/fluctuation. Furthermore, governmental and public bodies such as the Federal government, the Virginia Department of Transportation, and the Florida Department of Transportation have all recognized the criticality of the price escalation risk and accordingly allowed, with different approaches, the inclusion of escalation clauses in some of their contracts (Gallagher and Riggs 2006).

Price escalation clauses can help in minimizing claims between owners and contractors, and in the former receiving reasonable bid prices that are not loaded with high contingencies. However, even in such cases of having escalation clauses, if this market risk materializes, financial losses due to price fluctuation will still have to be incurred either by one of the parties or shared by both of them, as the escalation clause may dictate. Other mitigation measures that we found in the literature appear to be merely recommendations for better project and risk management so that the impact of the escalation risk is minimized. These mitigation measures; nevertheless, do not entirely obviate losses or curtail the materials price fluctuation uncertainty. To that end, the authors have initiated a research that targets to overcome this hindrance through applying, in the subject matter, means and methods typically used in relation to financial derivatives that can help both the owner and the contractor to hedge against price fluctuation risk. Our review of the literature indicated that this area of research, as related to the construction industry, has been largely disregarded. The first step of this research is determined to be the measurement of the volatility of the prices of three key construction materials; namely, cement, steel, and lumber in order to assess the degree and extent of this risk and evaluate the need for other suitable mitigation measures. Further research will aim at modeling and forecasting this volatility for an accurate estimation of the said market risk.

2 Literature Review

2.1 Introduction to Volatility Modeling and Forecasting

Volatility risk is considered as one of the main market risks that can be a source of uncertainty for institutions. In general, the term "market risk" refers to the likelihood that the value of a certain portfolio and/or asset will reduce due to changes in market factors (Ladokhin 2009). The significance of market risks stems from the fact that they can have a serious impact on the value of the exposed institution. Market changes that are not foreseen can potentially result in severe losses; and thus institutions linked to financial markets must estimate these risks (Ladokhin 2009). One of the methods used for estimating market risks is conducting volatility studies.

Volatility studies are studies that are concerned with the variability of one (or more) price series around its central value and are often used as a crude measure of the total risk of financial assets (Brooks 2002). In other words, these studies examine individual price observations tendency to deviate far from the mean value (Huchet-Bourdon 2011). It is noteworthy that volatility measures the outcomes spread, which can include both positive and negative outcomes (Ladokhin 2009). A plethora of research by academics and practitioners has been devoted to the modeling and forecasting of volatility, a concept that is often argued to be one of the most important in the entirety of finance (Brooks 2002).

As defined above, volatility measures the probable movement of the value of an economic variable. When the movement of the price over a short period of time is wide, this is universally referred to as "high volatility" (European Commission 2009). This condition may directly affect the ability of buyers/consumers to control their input costs and secure goods and hence affect the business. It is noted that high volatility can occur due to several economic and non-economic reasons; however, the determination and analysis of these reasons is out of the scope of this paper.

2.2 Historical Volatility vs. Implied Volatility

The literature includes two main kinds of volatility, historical volatility (HV) and implied volatility. In brief, historical volatility is based on observed past prices whilst implied volatility is based on the expectation of the market and on how the price will be in the future (Huchet-Bourdon 2011). Both kinds are explained in more details in the next paragraph.

Historical volatility, also known as realized volatility, is calculated using the realized movements of price over a historical period. It is a representation of the past price changes and it reflects the resolution of supply and demand factors (European Commission 2009). A common method for measuring historical volatility typically involves calculating the standard deviation of the returns over a period in the past and then using the calculated volatility as forecast for future periods (Brooks 2002). There are more sophisticated time series models, which can be used for the modeling of historical volatility; nevertheless, this paper utilizes the standard deviation approach as it is deemed sufficient for use when prediction of *future* price movements based on historical performance is limited. Implied volatility, on the other hand, corresponds to the market's view on the future volatility of an asset and how its price is likely to move. This kind of volatility is considered to be more responsive to the current market conditions since it can be greatly affected by certain market events, such as a company's announcements of profits or losses, making it a non-static forward-looking measure (Daily Theta n.d.). In contrast to the backward-looking historical volatility, implied volatility is used to monitor the opinion of a particular market about the volatility of an asset (typically a stock) (Hull 2008)

2.3 Volatility Measurement and Modeling

There are multiple volatility measurement and modeling techniques that can be found in the literature. In this section we will describe briefly two approaches, which are the standard deviation measurement of volatility, and Conditional Heteroskedasticity models (e.g. ARCH and GARCH). For extensive information on volatility modeling and forecasting, econometrics and financial risk management books such as those written by Bauwens, Hafner, Laurent (2012), Dowd (2007), McNeil, Frey, and Embrechts (2005), and Francq, & Zakoian (2011), just to name a few, can be useful.

Standard Historical Volatility Estimate

The standard deviation volatility calculation method is a basic technique that is occasionally referred to in the literature as the "standard historical volatility estimate" (Figlewski 1994). This is the technique followed in this paper. For the computation of volatility using this approach, first consider a set of historical prices for any material or asset: $\{S_0, S_1, S_2, \ldots, S_T\}$ where S_T is the price of the material/asset on day T. Secondly, measure the price changes by calculating the log relative returns (R_t) as follows (for t ranging from 1 to T):

[1] $$R_t = \ln(\frac{S_t}{S_{t-1}})$$

The above return is characterized by the values of the mean and the volatility (Ladokhin 2009). The mean of R_t (the average return over T periods) can be estimated as the simple average of R_t:

[2] $$\mu = \frac{\sum R_t}{T}$$

Whereas the variance of R_t can be calculated as follows:

[3] $$v^2 = \frac{\sum (R_t - \mu)^2}{(T-1)}$$

Taking the square root of the variance yields the historical volatility σ. The variance can be then annualized by multiplying by the number of price observations per year (N) before taking the square root. The formula for the calculation of the annual historical volatility can be then written as follows:

[4] $\sigma = \sqrt{Nv^2}$

Conditional Heteroscedasticity Models

Traditional economic models assume that any modeled distribution has a one-period constant variance. To overcome this flawed assumption, the Autoregressive Conditional Heteroscedastic (ARCH) model was first developed by Engle (1982) followed by its generalized form, GARCH, introduced by Bollerslev (1986). In other words, these models distinguish the difference between unconditional and conditional variances and they allow the conditional variance to change over a period of time as a function of past errors (Matei 2009). The ARCH and GARCH models and their subsequent extensions have become, since their development, amongst the most prominent tools used for capturing the changing variance of a distribution (Floros 2008) and ultimately for the measurement of volatility.

In equation form, ARCH model can be defined as follows (adapted from Ladokhin 2009):

[5] $r_{t+1} = \mu + \varepsilon_{t+1},$

[6] $\varepsilon_{t+1} = \sqrt{h_{t+1}} z_{t+1},$

[7] $h_{t+1} = \alpha_0 + \sum_{j=1}^{q} \alpha_j \varepsilon^2{}_{t+1-j},$

where

h is the variance of returns σ^2
$\boldsymbol{r_{t+1}}$ is the conditional estimate of returns at time t+1,
$\boldsymbol{\mu}$ is the mean return which can be taken as equals to zero,
$\boldsymbol{\varepsilon_t}$ are the error terms (residuals),
$\boldsymbol{z_{t+1}}$ ~ iid N(0,1) normally distributed random variables,
$\boldsymbol{\alpha_0, \alpha_1, \ldots, \alpha_q}$ are the model parameters.

The above model is named "autoregressive" because the term $\boldsymbol{\varepsilon_t}$ depends on the previous $\boldsymbol{\varepsilon_{t-i}}$, and is named "conditionally heteroscedastic" because of the continuous change of the conditional variance (Ladokhin 2009). One of the idiosyncrasies of the ARCH model, as determined empirically, is that it requires a high order parameter to appropriately capture the dynamic behaviour of the conditional variance (Alberg, Shalit, and Yosef 2008). Accordingly, a more generalized form of the ARCH model, universally referred to as GARCH, was developed by Bollerslev (1986) in order to fulfill this requirement, as it allows reducing the estimated parameters number from infinity to two (Alberg, Shalit, and Yosef 2008). Moreover, the definition of the GARCH model can be written in equation form as follows (adapted from Ladokhin 2009):

[8] $r_{t+1} = \mu + \varepsilon_{t+1},$

[9] $\varepsilon_{t+1} = \sqrt{h_{t+1}} z_{t+1},$

[10] $h_{t+1} = \omega + \sum_{i=1}^{p} \beta_i h_{t+1-i} + \sum_{j=1}^{q} \alpha_j \varepsilon_{t+1-j}^2,$

where

h is the variance of returns σ^2
$\boldsymbol{r_{t+1}}$ is the conditional estimate of returns at time t+1,
$\boldsymbol{\mu}$ is the mean return which can be taken as equals to zero,
$\boldsymbol{\varepsilon_t}$ are the error terms (residuals),
$\boldsymbol{z_{t+1}}$ ~ iid N(0,1) normally distributed random variables,

$\boldsymbol{\omega, \alpha_0, \alpha_1, \ldots, \alpha_q, \beta_1, \beta_2, \ldots, \beta_p}$ are the model parameters.

The explanation of the algorithm that is used for the estimation of both the ARCH and GARCH model parameters is not within the scope of this paper; nevertheless, it should be noted that at time (t) all parameters are known and hence $\boldsymbol{h_{t+1}}$ can be easily calculated (Ladokhin 2009).

3 Data Collection

As provided earlier, in this research we measured the volatility of the prices of three key construction materials namely Portland cement ($/ton), structural steel ($/cwt), and lumber ($/mbf). We obtained our entire price data from online archived issues of the Engineering News Record (ENR) journal for all months starting January 2008 up to November 2012, a range that amounts to 59 monthly readings for each material type (ENR 2012). For all three studied materials, the prices included in the ENR represent a 20-city average price paid by a contractor for a given large order.

In order to compare the calculated volatility against a standard datum, we obtained the varying values of both the Building Cost Index and the Materials Price Index, also included in the ENR journal. The Building Cost Index is calculated based on 68.38 hours of skilled labor (20-city average) of bricklayers, carpenters and structural ironworkers rates, as well as the 20-city price of 25 *cwt* of fabricated standard structural steel shapes, in addition to 1.128 *tons* of Portland cement at the 20-city price, plus the 20-city price of 1088 *board-ft* of 2x4 lumber (ENR 2012). On the other hand, the Materials Price Index focuses only on the material component of the Building Cost Index described above (the weighted 20-city price movement of structural steel, Portland cement, and lumber).

The ENR journal provides a third index referred to as the Construction Cost Index, which is almost identical to the Building Cost Index but replaces the skilled labor component by another common labor one. However, this index is not considered herein in order to avoid redundancy since the variance between the skilled vs. common labor prices is not part of this research and only one of these indices is deemed sufficient for the purpose of analyzing materials prices volatility.

4 Data Analysis and Volatility Measurement

4.1 Preliminary Analysis

For the analysis of the obtained price data described in section 3 above, we first plotted the price movement of each material from January 2008 up to November 2012 in a graphical form. Please refer to figures 1, 2, and 3 below for the price movement plots.

A closer look at the data reveals that, out of the 58 data points that followed the first reading of January 2008, the price remained constant for two consecutive months in 10 instances in the case of cement, 3 instances in the case of steel, and that there has been always a change in price in the case of lumber. In other words, the price of lumber has never remained constant for two consecutive months. In addition, the price on a month can be considered to have increased when compared to the preceding month in 37 instances for cement, 36 for steel, and 21 for lumber; whilst on the other hand, it decreased in 11 instances for cement, 19 for steel, and 37 for lumber.

Secondly, in order to better understand the data sample, statistical parameters such as the mean, median, maximum, minimum, range, and the standard deviation were calculated for all three materials. These are provided in Table 1. By examining the calculated parameters, it appears that although the prices of lumber seem to fluctuate more often as compared to cement and steel, the steel prices appear to relatively have the widest range.

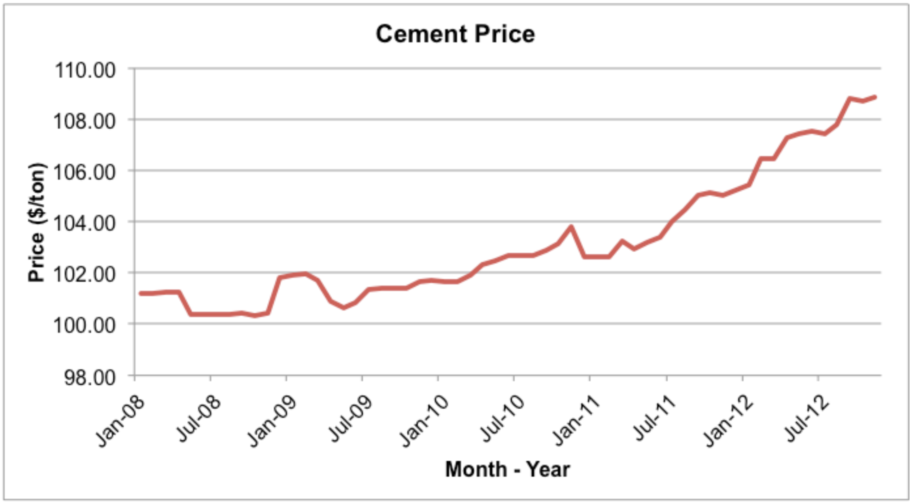

Figure 1 - Cement Price Movement

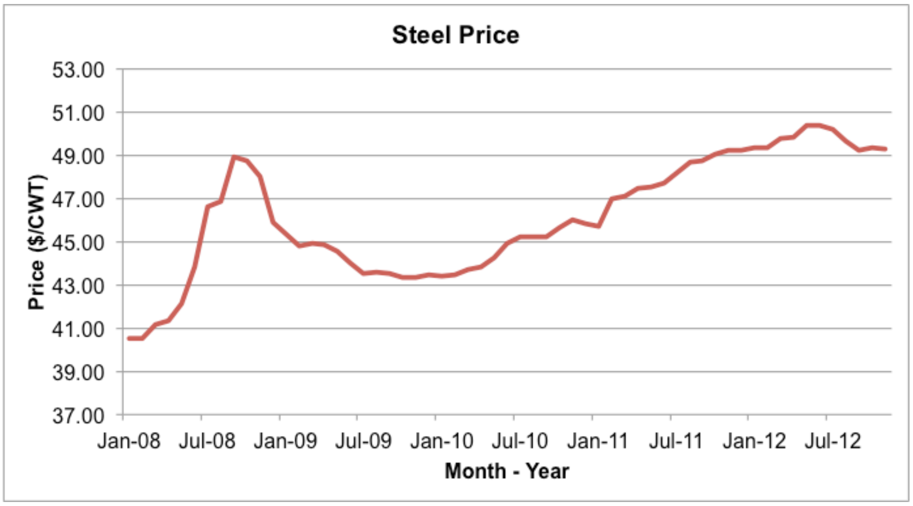

Figure 2 - Steel Price Movement

Table 1 - Statistical Analysis of Materials Price Data

	Cement	Steel	Lumber
Mean	103.15	46.15	405.33
Median	102.62	45.85	402.11
Max	108.84	50.40	432.93
Min	100.32	40.52	384.95
Range	8.52	9.88	47.98
Standard Deviation	2.44	2.71	13.59

Figure 3 - Lumber Price Movement

4.2 Volatility Measurement

The volatility was measured for all three materials (cement, steel, and lumber) in addition to that of the materials price and building cost indices using the procedure defined by equations 1, 2, 3, and 4, provided in section 2.3 above, by utilizing the Microsoft Excel application. Since the prices of December 2012 are not released yet by the time this paper is being written, these prices were estimated for comparison purposes using equation 4 in order to be able to come up with volatility figures for the entire year of 2012. As shown in Table 2 below, volatility was measured for each year individually and then for the entire 5-year period for the assessment of the long-term volatility of materials prices. For each material or index, the 5-year period price volatility was measured by collectively using the data of all years as a single series and considering the number of points (N) in equation 4 to be 60 (12 readings per year X 5 years). Table 2 shows the measured volatility for all material prices and indices obtained for this research. These measurements are compared by means of a histogram in Figure 4.

Table 2 - Volatility Measurements

Year	Cement	Steel	Lumber	Materials Price Index	Building Cost Index
2008	1.70%	9.78%	1.01%	6.53%	2.91%
2009	1.09%	1.97%	2.63%	1.12%	1.00%
2010	1.45%	1.80%	4.99%	1.97%	1.04%
2011	0.94%	2.62%	3.24%	2.20%	0.75%
2012	1.33%	2.20%	2.23%	1.57%	0.58%
5-year period	3.11%	11.34%	7.66%	7.95%	3.57%

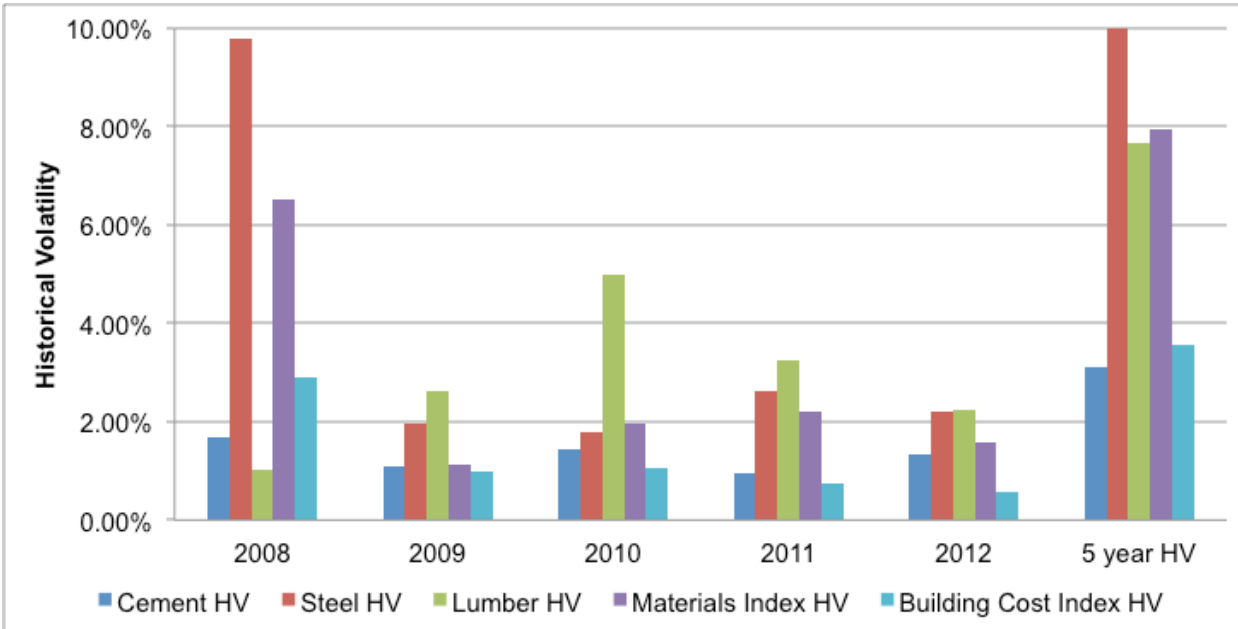

Figure 4 - Volatility Comparison Histogram

5 Discussion

By examining the calculated volatility, shown in Table 2, and the associated comparison histogram (Figure 4), it can be inferred that the volatility of the three examined construction materials is usually higher when compared to that of the Building Cost Index. This indicates that price movement of construction materials occurs more than that of the overall building cost. In other words, the possibility that a contingency allowance by a contractor is to be consumed by the volatility of construction materials seems higher than that of other building factors such as labor cost.

Cement price showed a relatively low volatility throughout the examined period even in the year 2008 of the financial crisis signifying a relatively stable market, since volatility did not exceed 1.7% in any of the covered years. This may require a further analysis in order to determine the reasons behind this considerable stability and to assess whether the cement market is oversupplied. On the other hand, steel had the highest long-term price volatility, which exceeded 11% when considering the entire 5-year period. This can be mainly attributed to the noticeably abnormal volatility of its prices in the year 2008, when the financial crisis was initiated, which came close to a staggering 10% in a single year. The dynamics of such peek will require further analysis to understand the reasons leading to such volatility. Over the short-term, lumber prices recorded the highest price volatility in the years 2009, 2010, 2011, and 2012 when compared to the volatility of the rest of materials and indices, a fact which suggests that contractors need to properly plan the purchase of lumber even when working on short-term projects because of the high probability of fluctuation of its prices. This price movement in both directions shall also require another study to gain insights about its potential causes.

Overall, it can be considered that the prices of steel and lumber are volatile and can possess a threat to contractors who try to minimize their contingency allowance in order to offer competitive tender prices. The volatility of the prices of these two materials is the main driver of the corresponding volatility of both the Materials Price Index and the Building Cost Index highlighting their significance.

6 Conclusion and Future Work

In this paper we calculated the historical volatility of three key construction materials; namely, cement, steel, and lumber. We also calculated the volatility of the Materials Price Index and the Building Cost

Index provided in the ENR journal to determine how does the volatility of these indices fare compared to that of the selected materials. The calculations showed that whilst cement consistently had low price volatility, the volatility of steel and lumber were often higher than that of the indices and can sometimes reach astounding levels that may result in significant losses to one or both of the project parties (contractor, owner, or contractor and owner) depending on the provisions of a price-fluctuation clause in the construction contract, if any.

The results of our analysis incite further research in multiple areas such as the use of more sophisticated volatility analysis and modeling techniques that incorporate time-varying volatilities as second step in the process of developing alternatives for hedging against the price fluctuation market risk. Other important areas include the determination of the dynamic impact of the global financial crisis and the volatility of the world's major currencies exchange rates on the construction industry in general and on the materials prices in particular, as well as the analysis of the economics of cement, steel, and lumber production and the impacting global and national demand and supply as related to the construction industry.

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