Mitigating Supply Chain Risks by Evaluating Supplier Bankruptcy Probabilities Through Web Services and the Black-Scholes-Merton Model

SHERIF BARRAD
Department of Supply Chain and Business Technology Management
Concordia University
1455 Boulevard de Maisonneuve West, Montreal, QC H3G 1M8
sherif.barrad@concordia.ca

RAUL VALVERDE
Department of Supply Chain and Business Technology Management
Concordia University
1455 Boulevard de Maisonneuve West, Montreal, QC H3G 1M8
raul.valverde@concorida.ca

Abstract: Industry consolidation and globalization represents a challenge for procurement organizations who typically become either recipients of the acquired company's supplier base or are directly responsible for this increase by securing new suppliers to meet the operational demands of a global supply chain. An increased supplier base not only makes it more difficult to manage suppliers but also represents higher supply chain risks. The proposed model attempts to proactively evaluate bankruptcy probabilities of suppliers by capturing financial information using web services, computing this data using a modified equation version of a well-known financial model and producing risk potentials, in percentage points, for supplier bankruptcies. The study clearly shows the usefulness of the prototype when operating in a Service Oriented Architecture and offered to end users as a leading indicator of risk.

Key-Words: Web Services, Black-Scholes-Merton, Supply Chain Finance, Supply Chain Risk Management

1 Introduction

Over the last two decades, industry trends such as consolidations through mergers and acquisitions (M&A), [1], [2] and globalization through e-commerce [3] and [4] have had direct impacts on procurement divisions of organizations by exponentially increasing their supplier base. When two companies merge, the acquirer automatically inherits the portfolio of suppliers potentially doubling the supplier base. From a globalization standpoint, companies reaching out to the global market must also in turn secure partnerships with global suppliers, which naturally also increase the supplier base.

As your supply chain extends and becomes more complex, not only does it cost more money to operate but it can also generate losses and costs, especially if a supplier fails to deliver or perhaps goes bankrupt. [5] argues that the recession has created treacherous business environments between suppliers and customers and, as a result, cash flow management now becomes one of the top priorities. If a supplier fails to deliver critical components, the client organization can find itself in a very precarious situation. Therefore, detecting the problem and protecting itself from such an event becomes a top priority. More broadly, and from a stakeholder perspective, [6] suggest that companies need to take account of external stakeholders when considering the drivers of M&A outcome and that strong partnership, only with key suppliers should be formed thus, eliminating the risk of supply chain disruptions.

Solutions to mitigate supply chain risks include developing contingency plans to address a suppliers failed attempts to deliver, renegotiating payment terms to create a financial buffer and working capital in case of customer imposed penalties however, as pragmatic as they sound, they may take long to develop and implement. Other potential solutions include optimizing agreements with existing vendors or perhaps even consolidating your supplier base. In fact [7], argue that, to develop effective partnerships, the supply base must be small enough in order to be manageable. Shrinking the supplier base becomes a long a tedious activity that can take years given the risks involved with disconnecting key suppliers from your supply chain. For example, transferring a multi-million dollar IT contract can take up to two years of preparation given the phased deployment approach typically used in contracts of this nature where business continuity is the top priority.

Several other solutions such as mixed integer non-linear programming (MINLP) models are brought forward [8] for order allocation considering different capacity, failure probability and quantity discounts for each supplier.

Information technology solutions exist to support supply chain management operations, these are referred as e-supply chain management systems. [9], showed that the profits of the firm increased and internal communications were improved due to the implementation of e-supply chain management systems. [10] proposed an s-supply chain management solution for the fraud reduction in procurement transactions by using data mining techniques that would help to reduce losses due supply chain fraud. E-procurement solutions, its integration with existing systems and benefits have been addressed by many research studies in literature [11], [12]. Although the benefit of e-supply chain systems has been supported by many studies in the past, the exploration of web services in supply chain is still an on-going effort that deserve attention in particular its application to e-procurement and risk management.

That said, this paper proposes a quicker and more efficient solution positioned upstream from the vendor and in the form of a web service to efficiently and objectively measure the probability of suppliers going bankrupt. This in turn can serve as an alarm to potential supply chain disruptions and leading to potential supplier bankruptcy.

1.1 Supply Chain Finance

Supply chain can be referred as the exchange of goods, information and finance. In recent years, supply chain finance has been identified as an emerging trends given it’s importance on company profitability. Supply chain finance refers to transaction activities and cash flow that go from the customer’s initial order to the seller’s pocket [13]. Supply chain finance can also be described as the sequence of financial events and processes that take place as commercial transactions are executed, [14]. More and more companies are signing on for supply chain finance in order to find ways to balance their need to take longer to pay their suppliers, [15].

Organizations that operate the financial portion of the supply chain typically deal with improving cash flow, managing supplier risk, financing global supply chains, optimizing tax effectiveness/working capital and finally, monitoring key financial performance ratios.

2 Materials and Methods

The following section describes the approach and tools utilized to design and conduct the study. To complete the proposed study, data will be retrieved from the web, computed using a mathematical equation (Black-Scholes-Merton Model) and the result will consist of a supplier bankruptcy risk in terms of percentage points.

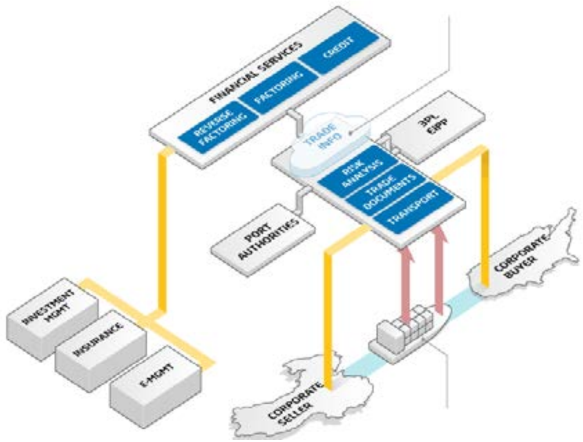

Fig. 1 – Activities in Supply Chain Finance

2.1 Data Collection

The research will use the Black-Scholes-Merton (BSM) [16] option-pricing model for estimating the probability of bankruptcy of suppliers based on the financial data collected for historical stock prices from the CRSP database (Centre for Research in Security Prices).

The data collected for this research will be collected by using a judgment sampling method. [17] acknowledge that judgment samples are inherently subjective but justify the use of judgment samples on the grounds that “samples are taken where individuals are selected with a specific purpose in mind, such as their likelihood of representing best practice in a particular issue”. From the outset it became clear that statistical sampling techniques on this type of research would have not been possible given the large amount of companies that act as suppliers for companies, this would have resulted an extremely high sample size that could not be computed for this dissertation given time limitations. The proposed sample size is 100 companies from a variety of industries operating in four different sectors: Energy, Consumer Durables, Technology, and Capital goods. These industries were judged appropriate for the study given their large number of suppliers and potential of losses due to supplier bankruptcy. This sample, in the opinion of the author, should be large enough to test the proposed model.

Data collected for the purpose of this analysis was obtained from two resources. First, listings were collected from NASDAQ's website (http://www.nasdaq.com/screening/companies-by-industry.aspx?) for organizations operating in four different sectors: Energy, Consumer Durables, Technology, and Capital goods (See figure 2). These industries were considered appropriate as organizations operating in these heavy or industrial goods industries will likely incur excess costs should a supplier declare bankruptcy. Examples of industries excluded were public utilities, transportation, and finance, which represent service based organizations that are not the focus of this research. In all, 1,046 company names were extracted, from which a convenience sample of 100 organizations was extracted.

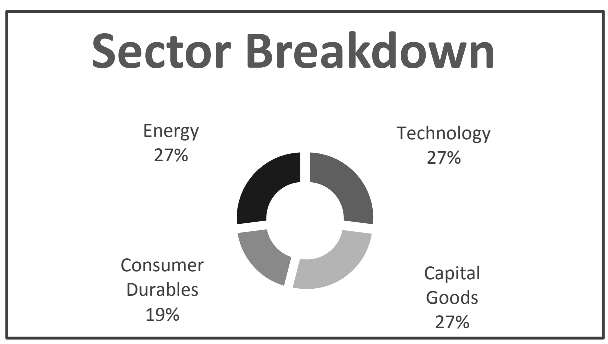

Fig. 2 – Sector Breakdown

The daily stock price data from January 1st 1994 to 2014 (the last twenty years) was then collected via the CHASS Data Centre (University of Toronto) CRSP Database, with the common assumption that the average number of Trading days in one year is 252.

The risk free rates for the last 10 years were downloaded (Bank of Canada, http://www.bankofcanada.ca/rates/interest-rates/t-bill-yields/selected-treasury-bill-yields-10-year-lookup/) for T-bills with 1-month, 3-month, 6-month, and 1-year maturity. A 10-Year average yield of the different term Treasury Bills was calculated and documented in table 1.

1-Month	3-Month	6-Month	1-Year	Average
0.0178	0.0186	0.0197	0.0197	0.0193

Table 1 Treasury Bills Free Rate

2.2 Web Services

Web services have been used to support business in the past, [18] proposed a web service architecture to support the integration of payment systems with point of sales terminals over the Internet. The idea of a web service architecture is to be able provide to systems an infrastructure to communicate and exchange date over the internet. Webs services are ideal for environments where data needs to be constantly updated by using the internet [19].

The regular market trades between 9:30am and 4pm EST with the first trade in the morning (opening price) and the final trade just before 4pm (closing price). Within this window, a stock price can change as often as every 15 seconds making the number of changes to a stock price excessively high on a daily basis. As the number of different stocks being followed increases, the occurrence of stock price changes become exponentially greater. The challenge lies in the ability to access "real-time" information effortlessly in order to support the risk model and to deliver the most up to date assessment on bankruptcy risks.

A web service is an efficient and an alternative data collection technique utilized to gather stock information periodically, effortlessly and to the user's required frequency (potentially in real-time). As opposed to a human intervention, web-services rely on computer-to-computer communications via a web network (web service). As described in the figure below, two entirely different environments, operating on different application servers with different hardware and programming codes can still communicate with one another using a "call" method. This notion can be referred to as "interoperability". In order for this to work, the web service must exist on both application servers. This requirement allows each environment to call methods from each other and share information (e.g. A Java piece of code can call a .NET web service for stock information and vice-versa). This "call" method can be identified as "Get Stock Information". This would in-turn execute the appropriate command to get the information required (such as market value of equity, risk free rate and other relevant stock information) and to ultimately compute the risk of bankruptcy.

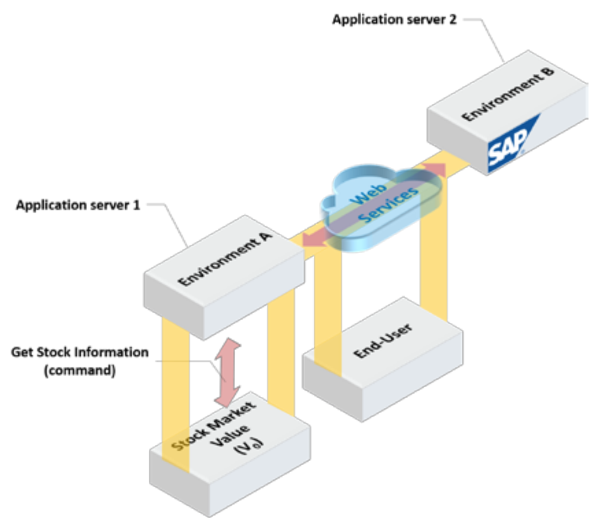

Fig. 3 – Web Service Prototype

The proposed web service would integrate in a Service Oriented Architecture platform making it available to selected users.

2.3 Service Oriented Architecture

The proposed platform suggests that add-ins can be developed and integrated into web services and that web services can then be proposed as "Add-ons" to existing ERP systems such as SAP. Once the prototype fully developed, data can be refreshed in almost real-time (15 sec refresh). Once the web service integrated into the ERP, it can now collaborate with other ERP modules (i.e. SRM, SCM, CRM) to manage supplier. The advantage of this platform consists of the fact that a web service, as opposed to a program, can be integrated into the services layer and offered as one service to many users thus, lowering IT costs.

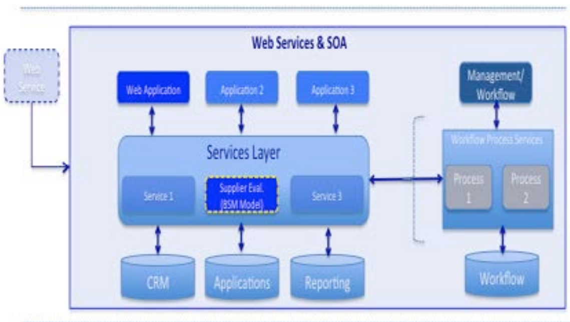

Fig. 4 – Service Oriented Architecture

2.4 Black-Sholes-Merton Model

The BSM model is used to calculate the probability of bankruptcy for the sample of firms selected for this study. [20] have proposed this model for supply chain finance with good results. The equation for valuing equity as a call option on the value of the firm's assets is given in equation 2 [21]. This equation is modified for dividends and reflects that the stream of dividends paid by the firm accrues to the equity holders.
The BSM equation is:

Equation 1

$$E_0 = V_0 N(d_1) - De^{-rT} N(d_2)$$

Where $N(d_1)$ and $N(d_2)$ are the standard cumulative normal of d_1 and d_2 which are:

Equation 2

$$d_1 = \frac{\ln(V_0/D) + (r + \sigma_V^2/2)T}{\sigma_V \sqrt{T}}; d_2 = d_1 - \sigma_V \sqrt{T}$$

E_0 is the current market value of equity; V_0 is the current market value of assets; D is the face value of debt maturing at time T; r is the continuously-compounded risk-free rate and σ_V is the standard deviation of asset returns.

Equation (3) [21] together with the option pricing relationship described in equation 2 enables V_0 and s_V to be determined from E_0 and σ_E.

Equation 3

$$\sigma_E E_0 = \frac{\partial E}{\partial V}\sigma_V V_0 = N(d_1)\sigma_V V_0$$

Under the BSM model, the probability of bankruptcy is simply the probability that the market value of assets , V_0 is less than the face value of the liabilities, D, at time T (i.e $V_0(T) < D$). The BSM model assumes that the natural log of future asset values is normally distributed. The probability of bankruptcy is a function of the distance between the current value of the firm's assets and the face value of its liabilities, adjusted for the expected growth in asset values relative to asset volatility.

As shown in [21], the probability that V_0 (T) < D or probability of bankruptcy can be calculated as indicated in equation 5:

Equation 4

$$N(-d2)$$

A PHP program is developed in order to calculate the probability of bankruptcy with the help of the BSM model for the sample of selected companies. The BSM model is fed by using daily return data from the Center for Research in Security Prices database (http://www.crsp.com).

The PHP program is used to calculate the probability of bankruptcy. The calculation is performed in three steps. In this initial step, E_0 will is set equal to the total market value of equity based on the closing price at the end of the firm's fiscal year, σ_E is computed by using daily return data from the historical stock prices from the Center for Research in Security Prices database (http://www.crsp.com) over twenty years of trading data. *D* is set equal to the book value of total liabilities, T is equal to one year, and r is set at the one-year treasury bill rate. In the second step, the values of d_1, d_2, σ_V and V_0 are estimated by simultaneously solving equations 1, 2 and 3.

Finally, the value of d_2 is used to calculate the probability of bankruptcy for each firm-year via equation 4 by using the standard normal distribution of $-d_2$.

3 Results and Discussions

A prototype was built for this research, a plug-in for SAP was created and a web service in PHP was built for the purpose of this research. The probability of bankruptcy for a sample of 7 companies was calculated by using the plug-in to generate the results below.

3.1 Probability of Bankruptcy

Company	Sector	Probability of Bankruptcy
CROWN HOLDINGS INC	Consumer Durables	0.99612488
TEXTRON INC	Technology	0.00022919
TECH DATA CORP	Technology	0.16963718
APPLE INC	Technology	0.00015289
SPARTON CORP POWER SOLUTIONS	Energy	0.00054959
INGERSOLL-RAND PLC	Capital Goods	1.2881E-06
NF ENERGY SAVING CORP	Energy	0.23296333

Table 2 Probability of Bankruptcy of Supplier Samples

Future research should also focus on the development of losses models that can estimate the losses of bankruptcy per supplier. This research assumes that these losses are given but in practice these losses would need to be estimated by insurance companies. A losses model would be required for this task in the future.

4 Conclusions and Limitations

The BSM used for the proposed model presents some limitations that can make challenging its implementation. The BSM model relies on financial public information that can be used to feed the model, this could be an important limitation given the fact that not all the suppliers are public companies that are traded in the stock market. Another limitation consists of the computation complexities associated with computing 4 non-linear equations simultaneously. This takes a considerable amount of time and as the prototype is enhanced, an optimized formulation approach may be required to reduce the time it takes to compute risk, especially with an increasing supplier base.

Future research should also explore the use of different bankruptcy models and measure the performance of these models against the BSM model. Although the BSM model proved to be robust for the proposed application, the literature in the field has several bankruptcy models that might be more suitable for the intended application in this research. For example, the model proposed by [22], requires less data that might be hard to get for 1this type of analysis and explores the use of cooperative models and bootstrapping strategies for default prediction. The use of this model in combination with risk pooling and Monte Carlo simulations can be explored as a possible solution to the lack of availability of data for non public suppliers as proposed by[23].

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Appendices

Appendix A– XMS Request and Response Sample to retrieve bankruptcy information

Below is a sample request and response to get the bankruptcy probability from Yahoo

```
<Request>
  <?xml version="1.0" encoding="UTF-8"?>
  <Record>
  <Ticker>YHOO</Ticker>
  <CompanyName>Yahoo, Inc.</CompanyName>
  </Record>
 </Request>
<Response>
  <?xml version="1.0" encoding="UTF-8"?>
  <Record>
  <Ticker>YHOO</Ticker>
  <Probability of Bankruptcy>0.06678632 </ Probability of Bankruptcy>
  </Record>
 </Response>
```