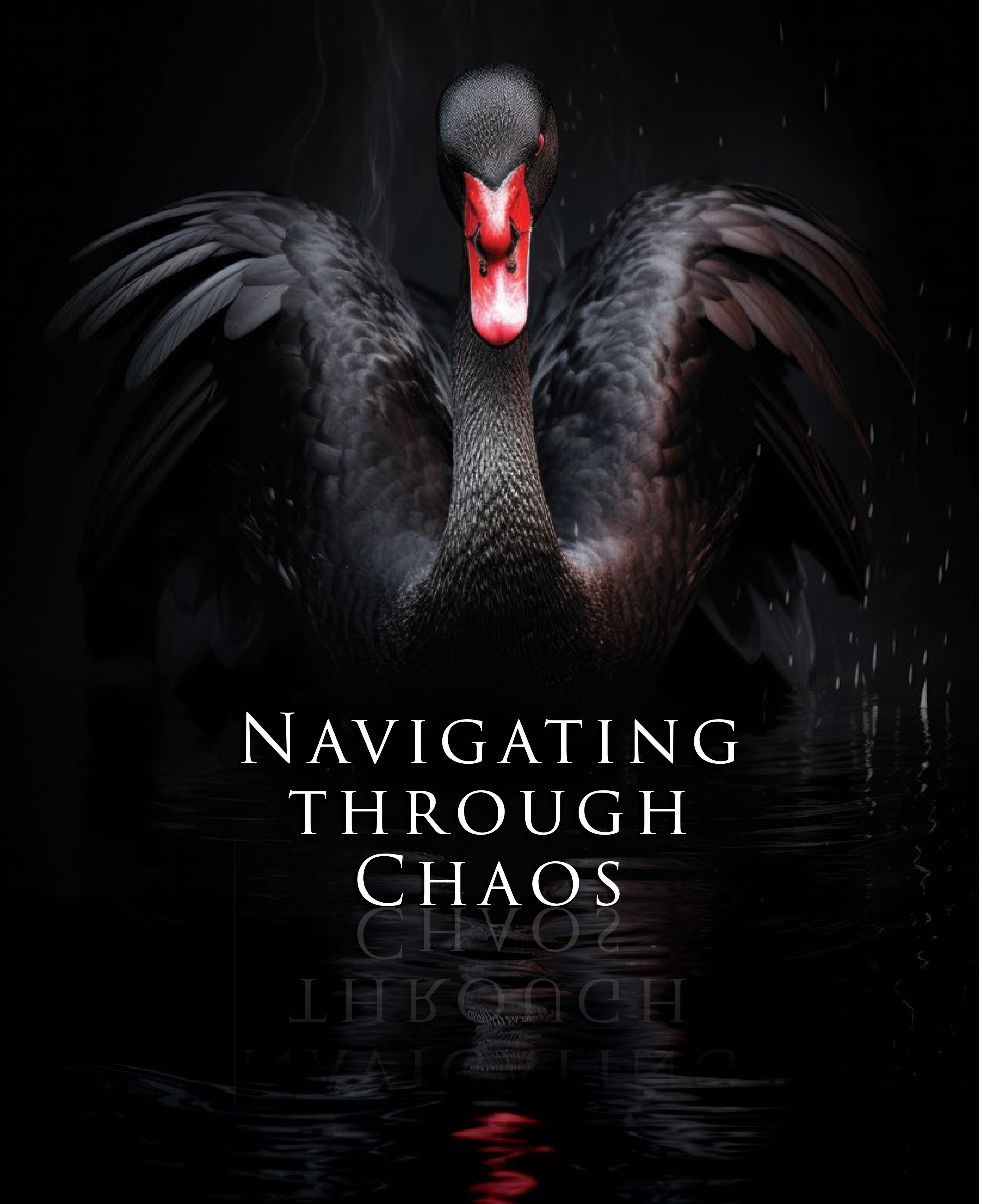

NAVIGATING THROUGH CHAOS

How AI and optimisation models can strengthen supply chain resilience.

by Lau Hoong Chuin

COVID-19 unleashed a wave of lockdowns globally that brought unprecedented supply chain disruptions between 2020 and 2021. The resulting estimated annual losses at some of the world's largest organisations topped US$184 million during that period, with 2022 bringing some relief and an average 50-percent reduction in red ink.[1] Even Toyota, the inventor of the 'just-in-time' system of supply chain and inventory management, told its semiconductor suppliers to increase their customary three-month inventory levels to last them for five months in a bid to strengthen its supply chain resilience.[2]

In a joint project by IBM and Singapore Management University (SMU) that commenced in 2021, my colleagues and I developed a data-driven Artificial Intelligence (AI) optimisation model that considered the likelihood of COVID-19-related lockdowns in various cities where IBM sourced its hard disk drive (HDD) components. The model improved IBM's supply chain resilience, helping it save US$1.8 million in the first year, and is projected to save up to US$35 million annually across the entire IBM infrastructure globally.[3] This project also won the 2023 Manufacturing Leadership Council Award in the Digital Supply Chains category.[4]

In this article, I will explain how we leveraged the power of AI to quantify risks to the supply chain and develop a scenario-based optimisation model. We also discuss how organisations can adopt the technology going forward.

BUILDING OUR MODEL: THE SCENARIO-BASED OPTIMISATION APPROACH

When considering possible supply chain disruptions, organisations traditionally look at the occurrence and frequency of situations such as natural disasters (earthquakes, floods, typhoons, etc.), labour disputes (strikes), and government policy adjustments (tax exemptions, tariffs, etc.). These geographical, political, and economic uncertainties are the traditional markers of risks associated with buying from any individual supplier, and years of data have been collected and built up to form a basis for risk assessment.

When the COVID-19 pandemic hit the world with full force in 2020, the questions became: How do you accurately predict such 'black swan' events, including the lockdowns? What data do you need to make such predictions? Companies that straddle cross-border supply chains were particularly vulnerable and had to come up with a quantifiable way to measure risk and use that information to formulate their procurement strategy.

For any organisation that brings together hundreds, or even thousands, of parts to make a final product–automobiles, high-end computer servers, mobile phones, etc.–supply chain resilience is much desired. Figure 1 illustrates what we did to help IBM build its supply chain resilience.

Under the 'General Risk Criteria', we considered standard risks, which were supplemented by the emerging COVID-19 risks such as border restrictions, factory closures, and regulatory changes that took centre stage during the pandemic. As part of its operating procedure, IBM has assembled a wide array of information sources that includes macroeconomic data from the EIU (Economist Intelligence Unit) database; manufacturing and catastrophic data from the proprietary, cross-tier customer-supplier collaboration platform Resilinc database; together with data available in the public domain that assesses, but is not limited to, natural disasters, geopolitical (US-China 'country-of-origin' tariffs) issues, and other factors that might affect the supply chain.

We analysed this data and the information presented by the COVID-19 data. We looked at 19 risk criteria that included political stability, tax policy risk, and natural disasters. We then applied a dimension reduction technique–factor analysis–to represent the data using just a few latent variables that can explain the correlations among these risks, with the final product being a number (ranging from 0.01 to 0.99) that describes the degree of correlation among the 19 risk factors.

All that information, which includes the probability of any single event happening, was crunched to produce a supplier risk score, which was then fed to the risk-constrained optimisation model that my colleagues and I developed for the project.

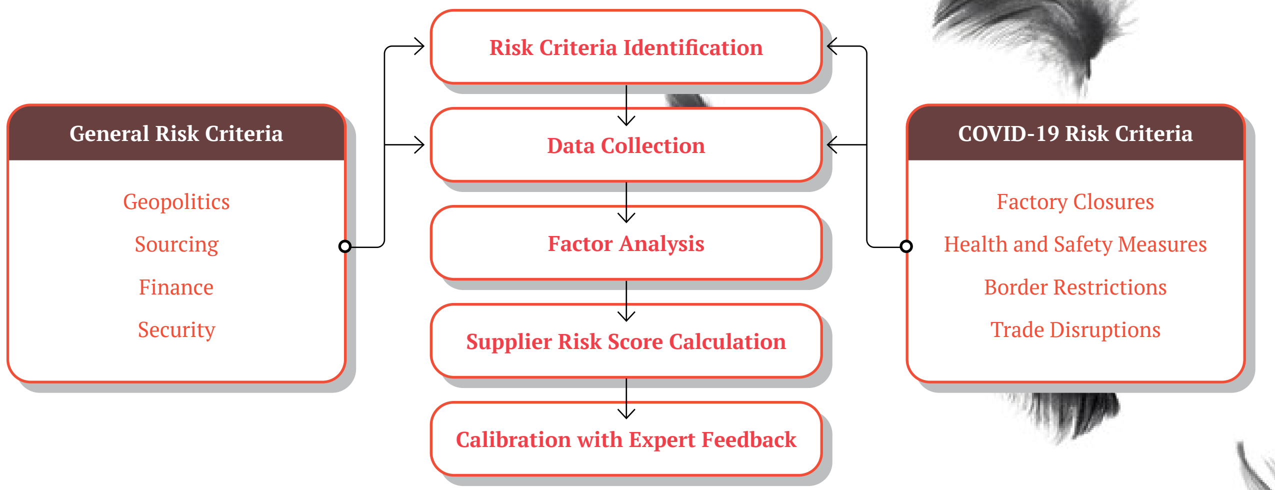

FIGURE 1

Source: Jonathan Chase, Jingfeng Yang, and Hoong Chuin Lau, "Risk-Aware Procurement Optimization in a Global Technology Supply Chain", International Conference on Computational Logistics 2022.

Thus, as observed from above, the COVID-19-related factors were not used to calculate the risk scores. Instead, they were used to generate scenarios for the scenario-based optimisation models. In other words, there are two categories: the traditional factors that contributed to the supplier risk scores, which were used in the optimisation model, and the COVID-19 factors which contributed to the scenarios that were fed into the model.

A key consideration for using the optimisation model is the presence of multiple suppliers for a specific interchangeable or replaceable component. Assuming a high-end computer server consists of 1,000 parts and each part is produced by multiple suppliers in various locations, a manufacturer must then decide how many units to buy from a specific supplier. If the supplier produces multiple necessary components, should the manufacturer procure from it more than just one component? One could adopt a broad-stroke approach by excluding all suppliers in locations that have experienced multiple lockdowns, but that is a coarse-grained way of decision-making.

Also, because our scenario-based optimisation approach is based on a high-fidelity model that is as close as possible to real-world uncertainty, we would be able to predict, with some scientific backing, the trigger and duration of lockdowns. The idea is that such a model can help inform the decision of which supplier to buy from, and how many units to buy, in anticipation of future lockdowns.

To illustrate, let us single out a single product we shall call Product Z1234, which is produced by 42 suppliers in our project. These suppliers are anonymised except for the country where they reside. Their risk scores are computed using our optimisation model, and then ranked based on COVID-19 factors such as lockdowns. When these same 42 suppliers are assessed on traditional risk factors, we find that those in China have significantly higher COVID-19-related risks vis-à-vis those in other parts of the world such as North America, Central America, and other parts of Asia.

Securing the necessary COVID-19-related data was key. Our project is built on epidemiological data that illustrated patterns of infection, lending themselves to inferences of how subsequent lockdowns may play out (e.g., when lockdowns will be triggered, how long they will last, etc.). We built on existing works to determine the infection rate,[5] while we developed a regression model to predict the duration of the lockdowns.

Hence, while we used historical data that is available online to build our optimisation model,[6] in future cases where data might not be readily available, organisations might need to provide a 'best-guess' estimate to run the model.

DEPLOYING SCENARIO-BASED OPTIMISATION MODELS EFFECTIVELY

High-end hardware can cost upwards of thousands of dollars, which translates into millions saved—or wasted—when factoring in the scale of multinational heavyweight companies. Efforts to realise such savings must take into consideration existing customer demand, supplier obligations and inventories. The objective is to strike a balance between cost and resilience.

The findings of my project are applicable so long as there is a large number of parts or components that interact with one another such that an optimisation approach is deemed

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necessary. For companies looking to adopt a risk-based approach to procurement and supply chain resilience, having the right data will be key. Readily available information such as the identity of suppliers, the parts/components they supply, the frequency of orders, and the price, along with other key data, will improve the accuracy of the model.

For smaller companies without the resources of global heavyweights such as IBM, there are open data sources such as Open Data Watch from which one can find valuable information.[7] Open-source initiatives proliferated during the pandemic, which led to innovative projects such as the Theia thermometer[8]. Resourceful use of such free and low-cost options can also produce concrete results.

CONCLUSION

Going forward, organisations large and small can look at scenario-based optimisation models beyond the context of COVID-19. The world may have seen off the last pandemic but the preparedness and resilience of businesses for the next one is unknown. The attack on commercial shipping traffic in the Red Sea is the latest reminder of the unpredictability resulting from geopolitical tensions, while the increased occurrences and severity of extreme weather have placed added demands on supply chain resilience. At the very least, such models represent a ready fallback if and when a pandemic-like event wreaks havoc on global supply chains.

A well-designed AI-based optimisation model can be adapted for use in fields beyond business. For governments, the scramble to procure masks, vaccines, and food supplies in early 2020 drives home the point that the 21st century is a time of vulnerability. Those without a resilient model will be in for surprises, often unpleasant. Procurement strategies at a national level are essential. Early adoption of such strategies and models provides opportunities for feedback and refinement, thus enhancing resilience.

COVID-19 has caused the biggest shock to global supply chains in recent years, and multinational companies have learnt invaluable lessons dealing with the unprecedented scale of disruption. Moreover, AI technology has developed sufficiently to take into account a wider array of data than had been available ever before. In the case of our project, that data—infection rate, duration of lockdowns, etc.—is used to build the scenario-based optimisation model into which traditional data is fed to derive a quantitative score to help smooth out possible kinks in the supply chain.

Such a scenario-based approach can help planners make more risk-tolerant, cost-effective global supply chain decisions. It can also be applied to other situations where traditional and plentiful historical data can be allied with AI to help with decision-making. Access to reliable data will be key, but there are plenty of publicly available sources. Decision-makers, be they in private or public organisations, would do well to invest in such capabilities before the next black swan event hits. AMI

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Endnotes

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