Calculating Financial Business Risk to Identify Supply Chain Vulnerabilities

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ABSTRACT

The COVID-19 pandemic has highlighted the vulnerabilities of supply chain systems, and companies must take Supply Chain Risk Management seriously to build resilience against future unknown disruptions. However, measuring risk and its impact is challenging due to data availability, interpretation of different types of risks, and complex product-supplier networks. Xylem, a global water technology company, posed a challenge to the capstone team to quantify the impact of risk using revenue as a measure. The team developed a Python program to quantify the impact of risk by suppliers, called Business Risk value, which is based on mapping parts, suppliers, models, and revenue in a structured and objective manner. In contrast, Xylem's previous approach lacked transparency and standardization. The team found that procurement spending is not simply correlated with the revenue impact of the company. The new Business Risk value can capture suppliers whose actual Business Risk value is high but went undetected in the old method because their procurement spending was low. The old method prioritized suppliers with high procurement spend, which may not add up to the actual revenue impact and creates unnecessary redundancy in the supply chain. The team suggests that Xylem expands the global database to include smaller suppliers to focus on mapping at least the Business Risk value throughout the supply chain to build resilience. Additionally, the team recommends mapping Time-to-Survive (TTS) to include as an indicator for the duration of impact time, which has not been factored in until now.

ACKNOWLEDGMENTS

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Chapter 1

1. Introduction

1.1   Company Overview

Xylem is a leading global water technology company that has global operations in over 50 countries and over 400 locations. Their products are distributed to over 150 countries, and they work with more than 20,000 suppliers globally, where roughly 8,000 suppliers supply components and parts for their assembly lines. These suppliers are referred to as their direct suppliers (Tier-1).

The number of suppliers that Xylem works with poses a challenge in monitoring and managing supply chain risk in a coordinated and structured way. Prior to 2019, monitoring and managing risk in Xylem was locally managed at each manufacturing site. Any disruption amongst their suppliers could negatively impact on the company's ability to manufacture and distribute its products. Challenges such as transparency, communication and synchronization during a crisis can add to the impact of the disruption. Ultimately, its damaging consequences are not only financial, but also compromise the company's ability to fulfill an important mission to provide water accessibility around the world.

Xylem established a Central Risk Team in 2019. The Supplier Risk Management Program was introduced. The program consists of four iterative process steps—identifying, assessing, mitigating, and monitoring risk—a framework that follows the outline proposed by Hallikas' et al. (2004) . Due to the complexity of the company's IT systems and database management, Xylem strategically

focuses on the Tier-1 direct supplier base. Roughly 4,500 of the 8,000 suppliers are actively

monitored for potential risks in the supply chain by using the risk management software

Riskmethods. The actively monitored suppliers roughly represent 90% of the total Tier 1 direct

supplier procurement expenditure.

1.2   Project Drivers and Motivation

Global market forces, technological forces, global cost forces, and political and economic forces are

what shape most complex supply chains today (Dornier, 1998, as cited in Simchi-Levi et al., 2008).

These forces influence company strategic choices to take advantage of global demand, compete on

costs and technology, and leverage on trade agreements. As a result, complex networks with lean

and cost-effective supply chains that span across different countries and regions, increase the risks

in the supply chain network. Some strategic activities include outsourcing and offshoring of

manufacturing, sourcing in low-cost countries, and reducing inventories. They create uncertainties

and dependencies within the supply chain network (Norrman & Jansson, 2004; Wagner & Bode,

2006).

In a study conducted by the Business Continuity Institute (BCI, 2019), 56% of the surveyed

companies experienced a supply chain disruption in 2018 with no signs of abating over the 10-year

period that BCI has conducted this survey. Interestingly, BCI also reported that almost 1/3 of the

surveyed respondents did not invest in resources to identify the original source of disruption. A

long-term strategic perspective needs to be evaluated in terms of where to prioritize resources and

efforts to reduce the company's risks and assess the resilience of the company's supply chain. With

supply chain risks frequently occurring, these risks are increasingly difficult to manage with short-

term action plans without the employees in a company feeling like they are in a perpetual state of "putting out fires".

Since the COVID-19 pandemic, Xu (2021) pointed out the high state of vulnerability that companies' supply chains are operating under. Focusing on investing in resources to map their supply chain networks to identify the risks before deciding on long-term actions that will mitigate the risks, is strongly recommended. This recommendation is also echoed by Taghizadeh et al. (2021), who argue that an effective supply chain resilience strategy is needed, especially for companies that have complex and deep-tiered networks.

Failure to invest in resources to build a resilient supply chain can cause major financial impact on the bottom-line (Norrman & Jansson, 2004) and affect shareholder value (Hendricks & Singhal, 2003).

1.3   Problem Statement

Since the financial crisis of 2008, Xylem has started to invest in supply chain risk management to gain a better overview of their supply chain network. They have a company-specific method and framework (Supplier Risk Management Program) which measures the risk and impact levels of their suppliers on two metrics: Risk Score and Impact Score.

The Risk Score is based on various external risk sources (e.g., geopolitical stability, supplier financial stability, natural disasters, port delays, etc.) measured from a scale of 0 – 100. This should not be confused with the probability of a disruption occurring. The Impact Score is the severity of impact of a risk disruption, which is evaluated on a scale of 15 – 100. There is no 0 impact, but a

supply chain can sustain a 0-impact situation for a temporary period depending on the risk mitigation measures in place. This Impact Score is an internal measure designed by Xylem, based on four criteria: revenue dependency of Xylem on a supplier (Business Risk), flexibility of alternative sourcing (Supplier Availability), time to recovery (TTR), and Supplier Performance on delivery, quality, and relationship. These criteria are explained in Chapter 3.

Recently, the management team in Xylem has been interested not only in understanding the risk and impact of suppliers on Xylem's supply chain operations from these two metrics alone. The scores of 0 – 100 do not indicate the financial implications in the event of a disruption, and do not indicate whether certain risk mitigation plans are under- or over-invested in resources and efforts. The management interests are driven by a financial interest to understand the impact of risk at an aggregated view across different profit centers (a total of six profit centers). This led Xylem to develop a third metric called "Revenue at Risk", by interpreting the Risk Score and Impact Score with their financial revenue. This new metric, however, does not represent actual revenue at risk, despite Xylem coining the metric as such.

The need to have a financial view on risk and impact raises a key challenge and problem statement of this capstone. Firstly, the current Supplier Risk Management Program framework could not support the third metric to establish the financial impact of risk. There is limited value-add on risk management from a financial impact perspective. Secondly, the program framework does measure the financial impact of risk in the first criteria of Impact Score, but it is qualitatively evaluated based on bottom-up input from local manufacturing sites per supplier. Xylem could not extract this value from the Impact Score because there are no direct reports that link product revenue and the supplier's risk profile. Hence, this capstone investigates the current process of measuring the

financial impact of risk in the Impact Score and provides an improved process to quantify risk impact objectively. The challenge may seem simple. A similar project at a manufacturing site was tried before in 2019, but it failed. This was due to Xylem's complex system landscape and databases.

A second key challenge of this capstone is to respond to the Global Director of Supplier Risk Management's observation and intuition of heightened Impact Score levels. The director expressed that the impact on the business was potentially higher than the reality of actual business operations. High Impact Scores lead to the perception in management that there are not enough risk mitigation actions in place to manage and reduce the impact of risk.

In summary, Xylem has some interpretability issues in their current method of measuring risk and impact:

1) They have indeed quantified the financial impact of their supply chain but because of the complex system and data landscape, the financial impact is qualitatively assessed and is used as an estimation when assessing the Impact Score

2) To add to the complexity of interpreting their business risk from a financial perspective, they introduced Revenue at Risk, which is not an actual financial impact of risk. This metric was also not clearly defined at the time of the capstone's undertaking.

3) There is an intuition that the Impact Scores are too high, which affects the perception that there are not enough risk mitigation actions to manage risk.

Therefore, to address the issues stated above, the capstone aimed to achieve these objectives:

1) Improve the process of quantifying the financial impact of supply chain risk by bringing different sources of data on revenue, products, parts, and suppliers.

2) With the new financial impact of risk, identify unnecessary redundancies in Xylem's supply chain by highlighting suppliers' business risks that may be overvalued (overestimated).

3) At the other end of the spectrum, identify hidden risks that Xylem may have in relation to their current process of measuring business risk, which is currently undervalued and not captured in their current scoring method.

These objectives will serve as a pragmatic and simple framework for how an organization can map its business risk to obtain visibility of its supply chain network.

1.4   Capstone Structure

The capstone begins with an overview of supply chain risk management to set the stage for this project. This is followed by a description of the methodology that covers the steps taken to link the various databases together and by a description of the results output in relation to Xylem's current method. The capstone closes with considerations for scaling up the process method for a company-wide implementation and extensions to the Supplier Risk Management Program.

Chapter 2

2. State of the Art

2.1   Supply Chain Risk Management (SCRM)

Managing risks in the supply chain is an important topic in supply chain management practice these days, especially after the COVID-19 pandemic and the ongoing war in Ukraine. As such, the field of supply chain risk management (SCRM) is an important field of research within supply chain management. As described earlier when discussing the effect of globalization, supply chain management strategies responded to this effect through sourcing strategies, inventory policies, lean production, etc. The trade-off to cost-effectiveness is increased risks, and therefore, the practice of effective risk management is required. Figure 1 summarizes this field of research neatly, as an intersection between risk management and supply chain management (Paulsson, 2004, as cited in Khojasteh, 2018).

Figure 1

SCRM as the intersection between supply chain management and risk management
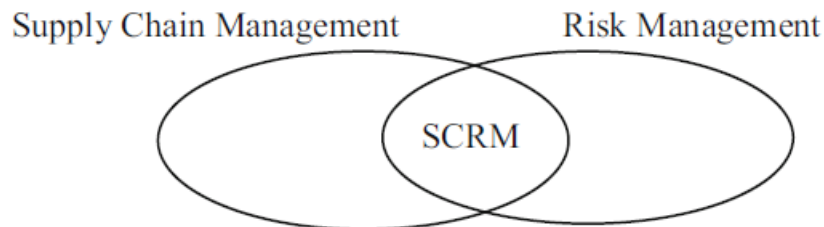
Note. From *Supply Chain Risk Management: Advanced tools, models, and developments (p. 7), by* Khojasteh, 2018, Springer.

While companies are met with the challenge to find a prescriptive framework to manage risks in their supply chains, the same challenge also presents itself within this field of research. There is a rich body of academic research in this field that has developed over the last 20 years (Choudhary et al., 2023; Katsaliaki et al., 2022), and that means that the definition of SCRM in practice is broad. Choudhary et al. (2023) emphasized that SCRM is a complex multi-disciplinary domain on the grounds that there are different approaches to SCRM which are needed for a thorough understanding of risk management. However, no matter the type of approach, SCRM cannot capture the entirety of risk management. From a business application point of view, a company that is establishing or practicing risk management is therefore unique and individual to the company.

In relation to Xylem and this capstone, this project uses Hallikas' et al. (2004) definition of SCRM which comprises four stages of risk identification, risk assessment, decision and implementation of risk management actions, and risk monitoring. The capstone's scope will be to review the company's risk identification and assessment phases.

Norrman & Jansson (2004) put forward a "quantitative definition" of risk = probability of event * business impact (severity of event), which is also visualized in a 2 x 2 matrix, as shown in Figure 2 (Hallikas et al., 2004; Norrman & Jansson, 2004)

Figure 2

Risk matrix probability and business impact

Note. Hallikas et al. (2004).

The simplicity of the "quantitative definition" offers companies a framework to manage high business risks by extracting events which has a high probability of a disruptive event occurring, or gauging where their vulnerabilities are based on the level of business impact should a disruptive event occur. However, the issue with the "quantitative definition" is that it misses the opportunity for companies to anticipate real uncertainties, which is low and unknown from a probability viewpoint. Not only that, but companies do also have in-built resilience strategies too which delays

the actual impact of disruption, and this is not entirely factored in this simple 2 x 2 quadrant. Finally, when referring to the quadrants, companies are least prepared when it comes to very low probability events that may have catastrophic consequences (Simchi-Levi et al., 2008). These disruptive events are famously known as "black swan" events, which the world has experienced in the past three years.

As such, to understand how supply chain risks can be managed, it is important to identify the types of supply chain risks prior to assessing the consequences of these risks in two separate steps.

2.2 Supply Chain Risk Identification – Types of Risks

Tang (2006) classified supply chain risks into four types: Supply Management, Product Management, Demand Management, and Information Management. Wagner & Bode (2006), on the other hand, categorized three types of supply chain risks. Similarly, they identified that risks could be found in the supply and demand management of supply chain operations, but they introduced a third category called catastrophic risk. Here, catastrophic risks refer to external forces that are beyond the control of normal supply and demand management such as natural hazards, socio- and geopolitical issues, and war. Around the same time, in another study, supply chain risk was categorized into more specific sub-types in relation to the supply chain risks within supply and demand management of supply chain management, and external forces. Chopra & Sodhi (2004) identified 9 types of risk categories: disruptions (external uncontrollable risks as defined by Wagner & Bode, as catastrophic), delays, systems, forecast, intellectual property, procurement, receivables, inventory, and capacity. Simchi-Levi et al. (2008) suggested that apart from identifying the types of risks, risks can also be characterized on a spectrum of controllable and uncontrollable risks (see Figure 3). Controllable risks are risks that are known and not known simultaneously. These types of

risks are typically variables within demand and supply management operations. Uncontrollable

risks are where the greatest risks lie, since there is no way to predict them or to prepare for them,

which the world has experienced lately (i.e., COVID-19, the war in Ukraine, and the Suez Canal

incident)

Figure 3

Risk sources and their characteristics.
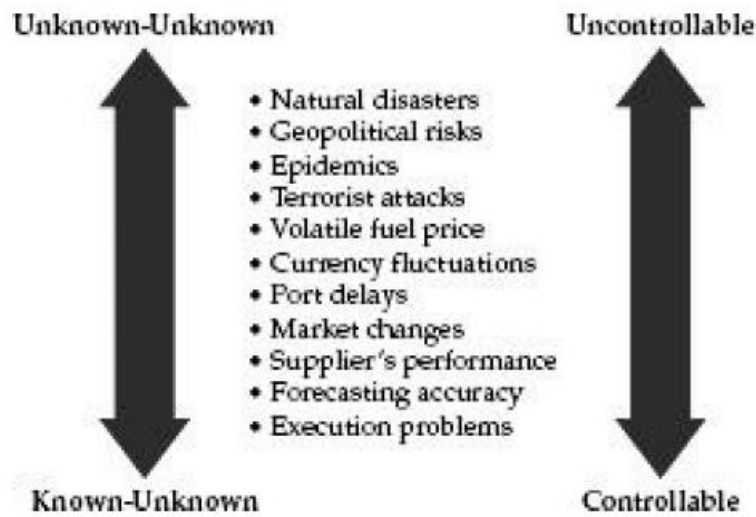
Note. From *Designing and managing the supply chain: concepts, strategies, and case studies*

(Chapter 10. Global Logistics and Risk Management, p. 591) by Simchi-Levi et al., 2008. Tata

McGraw Hill Education Private Limited.

Indirectly and intuitively, these supply chain risk categorizations provide an indication of the

probability of any of these types of risks occurring. Catastrophic risks, external disruption and

unknown-unknown/uncontrollable risks are where the probability of occurring can be very low and

undetermined, while operational inefficiencies and inaccuracies will have a higher probability of

occurring. To predict the probability of different types of events, however, is potentially possible,

but realistically not a pragmatic way to quantify and manage risks. Therefore, the other aspect of measuring risk is to consider the impact a disruption may have on the business.

In the event of a supply chain disruption, the intensity and duration of the impact also affects the severity of the impact. Disruptions that result in poor supply chain performance has shown to have financial implications to companies (Hendricks & Singhal, 2003). Some examples highlighted by Norrman & Jansson (2004):

- *Fires*: in 1997, Toyota lost about $325 million in products and disruption costs of $195 million.

- *Demand:* Cisco bled $2.5 billion from an inventory write-off in 2001 from locked-in supply agreements in a weakening market demand.

- *Supply:* Nike lost $100 million in sales from inaccurate supply planning in 2001.

In summary, formulating risk management strategies in supply chain risk management can be approached by deriving actions and strategies based on the identified types of risks. It can also be assessed based on the severity of the business impact in terms of revenue or profit. Both approaches are valid, but in the context of business operations where resources are generally limited, the latter approach to quantify the business impact and prioritize risk management strategies based on severity regardless of the probabilities, is seen as a more pragmatic approach. To simply put it, financial impact is a common business language shared by all stakeholders in the business. Supply chain disruptions have financial implications and affect shareholder value. Furthermore, the goal for any business is to maximize profits and reduce costs, and therefore it makes sense to prioritize risk management strategies based on business severity.

2.3   Supply Chain Risk Assessment – Quantifying Impact

According to Choudhary et al. (2023), supply chain risk assessment is also an important aspect of SCRM, but the literature on it has not been as developed as compared to risk identification or mitigation. Their research reviewed past literature and categorized the assessment criteria of risks and summarized the various techniques offered. The assessment criteria are detectability, risk exposure, avoidance, likelihood, impact intensity, impact time, expected utility and cost (see Figure 4). This expanded the earlier literature of identifying and assessing risk on a simple 2 x 2 matrix of probability and impact.

Figure 4

SCRA decision-making parameters

Detectability

Are the disturbances in an organization (or multiple organization in a supply chain) detectable?
Can the disturbance be attributed to an event?

Risk Exposure

How many risky events is an organization faced with (or multiple organizations in a supply chain)?
How long are the organizations exposed to such risks?

Avoidance

Can the events be avoided?

Likelihood

What is the likelihood of occurrence?
Can the risks be compartmentalised based on their probability of occurrence?

Impact Intensity

What is the intensity/severity if the risks manifest?
Are the risks measurable?

Impact Time

What is the duration of the risk's impact? When will a full recovery be achieved?

Expected Utility

Are there benefits associated with taking the risks?
What are these benefits, and how can they be measured?

Cost

What is the cost of aiming to predict risk events?
What is the cost associated with their mitigation and/or recovery?

Note. Choudhary et al. (2023)

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Based on these assessment criteria, one of the main themes of risk assessment methods that emerged was network-level risk assessment. The complexity of supplier and product networks these days because of globalization makes it a general study topic in this research field, in addition to the fact that companies struggle to deal with the impact of supply chain disruption (Zsidisin et al., 2005).

To emphasize the point regarding the complexity of supplier networks, Taghizadeh et al. (2021) demonstrated the improvement in assessing a supply chain's resilience by simulating disruption events using secondary information from third parties and guidance from domain experts. The usage of secondary information improves resilience assessment because at least 50% of all supply chain disruptions stem beyond the tier-1 supplier base (Allianz, 2014, as cited in Taghizadeh et al., 2021). The main challenge, however, is the data collection of secondary information and the validity of it as highlighted by the author.

Similarly, Brintrup & Perera (2019) approached the complexity of supplier networks by mapping the product interdependencies from raw materials to finished goods. This takes an indirect approach to supplier network mapping. By estimating these product interdependencies, the quantification of supply chain outsourcing risk can be determined. The challenge with this method is that it is highly dependent on large scale data to analyze these interdependencies.

The research challenges in these two examples around the network and product complexity are not impossible to resolve. From a business application point of view, however, the investment required to build complex supply chain network model can be tedious and potentially a waste of limited company resources. Should companies strive to improve and enhance their risk management

strategies, a method that balances resource limitation and granularity of the supply chain network is required.

This brings to earlier research conducted in 2015. Simchi-Levi et al. (2015) proposed a novel way of quantifying supply chain risk in Ford's automotive supply chain by quantifying the impact of disruption regardless of its risk types. It is also a network-based assessment, but this approach postpones the need to invest in resources to probe deeper into Ford's supply networks beyond their tier-1 suppliers. It assesses the time-to-survive (TTS) of its suppliers, the performance impact of the manufacturing sites of lost vehicle sales volume, and the relationship between supplier spend and the performance impact of lost profit at the site. Each results provides an insight into the weakness of the company's supply chain strategy and operations, which then allows the company to make their own decision on delving deeper into the vulnerabilities assessed and make decisions to mitigate these vulnerabilities. This approach balances the requirements for granularity and deep understanding and visibility of a complex supply chain network, and the investment of resources to manage risk in companies. The framework that Simchi-Levi has developed has since been implemented at Ford, Cisco, United Nations, etc. (Gao et al., 2019).

In the next chapters, the capstone will draw on Simchi-Levi's work, by reviewing the identification and assessment steps of Xylem's Supplier Risk Management Program. The objective is to map the revenue generated from one manufacturing site based on a map of its parts and components that is supplied by their suppliers and provide an overview of which suppliers have a high impact on Xylem's business. With the mapping of the business risk impact the suppliers have on the revenue, the company can have better clarity on how risks are managed. This means that the metrics of Impact Score and Revenue at Risk can be used for their actual intention and meaning, i.e., Revenue

at Risk refers to the severity of business impact, and Impact Score tracks the progress of risk

mitigation strategies.

Chapter 3

3. Xylem Supplier Risk Management Program

In business practice, the methods used to identify and assess risk in the supply chain depend on how a company chooses to identify the risk source: *"other firms adopting a supplier risk assessment and monitoring methodology will need to define risk categories based upon their own needs, industry type, supply chain type, etc."*(Blackhurst et al., 2008). Xylem has adopted its own risk management program; therefore, this section details Xylem's Supplier Risk Management Program, to set the scene to bridge the link between the literature reviewed in Chapter 2 and the methodology used in Chapter 4.

3.1 Overview

Recalling the various categorization of risk types and assessments, Xylem's risk program is dedicated to monitoring their network for most of their tier-1 suppliers that supplies parts for their assembly lines. Xylem's internal supply and demand operations are not in the scope of their risk management program but can indirectly impact operations based on supplier contract agreements, for example, inventory levels at a manufacturing site can depend on the supplier inventory and lead time agreements.

Figure 5 showcases the cycle of Xylem's Supplier Risk Management Program. In each step of the process, different reports are built and used to identify, assess, mitigate, and monitor risk. Xylem uses two metrics in the risk identification process: Risk Score and Impact Score. The third metric Revenue at Risk is a new metric that is primarily used for management reporting to represent the risks in different profit centers and does not influence the decisions made within this process. To

add to this, the definition of Revenue at Risk provided by the company was not clearly defined at the time this capstone is undertaken. Nonetheless, the outcome of this project can serve as the input for the company to mature this metric in the future for its intended purposes.

Figure 5

Xylem Supplier Risk Management Program
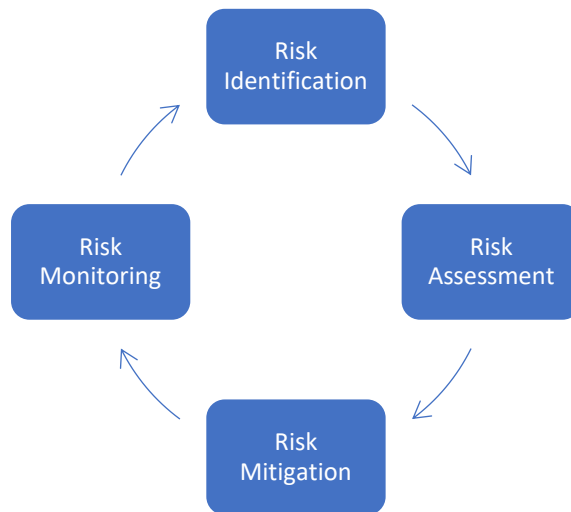
Note. From Xylem.

The scope of this project entails looking specifically into the risk assessment stage to quantify the actual revenue at risk (not to be confused with Xylem's Revenue at Risk metric). The project adopts the approach to assess the vulnerabilities and map out the revenue dependency of suppliers. The term that will be used for the actual revenue at risk is Business Risk Value, for the sake of clarity.

3.1.1 Risk Score

The Risk Score in Xylem's business is derived from *Riskmethods*, a supply chain risk management software to identify risks that are external to Xylem's control. These are the types of risks classified

as "catastrophic", "disruption", or "unknown-unknown" per the literature review. Each supplier is scored between 0 – 100. The higher the score, the higher the risk that Xylem is undertaking doing business with the supplier. While it is not an actual probability calculation, it is a scoring method to keep an eye out for suppliers that can disrupt business operations. The scoring is based on an assessment of 95 different risk indicators such as geopolitical changes, financial risks in a supplier, the quality and delivery of the supplier, weather, and ESG-related issues. Each of the indicators is weighted based on Xylem's assessment of which risk indicators impact Xylem's business and reputation more. The data is dynamic from *Riskmethods* and changes from day-to-day.

However, the downside to having many risk indicators is that it reduces the sensitivity to the weight assigned by Xylem to detect the risks that they may be more severely affected by. With 95 indicators where each indicator is weighted between 0 – 4%, the elements of risks become diluted. Table 1 details out each of the parameters and the weight of each parameter. For example, catastrophic risks such as natural hazards only weigh 1.60%. If there was an actual natural hazard and the indicator level was at 100, the resulting weight for the natural disaster only adds up to 100 * 1.60% = 1.6. In other words, the natural hazard hardly bears any "threat" to the supply chain. The only exception where a parameter supersedes all other parameters is when the indicator score is marked with KO, which will automatically put the supplier at score of 100.

Table 1 *Risk Score parameters and weight distribution.*

Risk Score parameters and weight distribution.

Area Risk Score		Risk Score		Indicator Score	
Image & Compliance	28%	Labour practices & human rights	12%	Human rights	4%
				Labor practices	4%
				Labor practices & Human Rights (Ecovadis)	4%
		Environmental	8%	Environment	4%
				Hazardous substances	4%
		Fair business practices	4%	Fair business practices	4%
		Sustainable procurement	4%	Sustainable procurement	4%
Finance	40%	RapidRatings Financial Health	37%	Financial Health Rating	3.20%
				Simulated Financial Health Rating	3.20%
				Core Health Score	3.20%
				Operating Profitability	3.20%
				Net Profitability	3.20%
				Capital Structure Efficiency	3.20%
				Cost Structure Efficiency	3.20%
				Delta Financial Health Rating	3.20%
				Delta Simulated Financial Health Rating	3.20%
				Leverage	2%
				Liquidity	2%
				Earnings Performance	2%
				Probability of Default	2%
		Credit Rating (CreditSafe)	3%	Credit rating	3%
		Bankruptcy	0%	Bankruptcy	KO
				Force Majeure	KO
Country/Location	30%	Disasters at business partner site	2%	Disaster at business partner site	KO
				Disaster on vessel	2.40%
		Natural hazards	19%	Earthquake	1.60%
				Volcano	1.60%
				River flood	1.60%

Area Risk Score		Risk Score		Indicator Score	
				Tropical cyclone	1.60%
				Wildfire	1.60%
				Extratropical storm	1.60%
				Flash flood	1.60%
				Hailstorm	1.60%
				Lightning	1.60%
				Storm surge	1.60%
				Tornado	1.60%
				Tsunami	1.60%
		Corruption or bribery	2%	Country corruption or bribery	1.60%
		Country Rating (S&P)	3%	Country rating	3.20%
		War	2%	War	2.40%
		Infrastructure	2%	Infrastructure	1.60%
Events	2%	Financial stability supplier	1%	Acquisitions	0%
				Revenue stability	0%
				Insurance coverage	0%
				Current ratio	0%
				Profit margin	0%
				Credit/Contract limit	0%
				Cash collection	0%
				Payment behaviour	0%
				Patents/Rights	0%
				Low-cost supplier threat	0%
				Field issues	0%
				Major product release delays	0%
				Revenue/Growth outlook	0%
				Short Term Financial Risk	0%
				Long Term Financial Risk	0%
				Mergers	0%
				Divestments	0%
				Insolvency under self-administration	0%

Area Risk Score		Risk Score		Indicator Score	
		Innovation potential	0%	Number of new patents	0%
				Key employee stability	0%
		Operational capabilities	0%	Manufacturing performance	0%
				Crisis management	0%
		Pandemic outbreaks	0%	Pandemic disease outbreak	0%
				Pandemic disease at location	0%
		Local events	0%	Civil unrest	0%
				Terrorist act	0%
				Disaster at location	0%
				Energy Outage	0%
		Staff disputes	0%	Industrial dispute at business partner site	KO
		Location disputes	0%	Industrial disputes at location	0%
		Information/IP Security	0%	IT & Telecommunication issues	0%
				Cyber attacks	0%
				Intellectual property (IP security)	0%
		Regulatory & Legal	0%	Sanctioned business partner	KO
				Sanctioned persons	KO
				Business partner fines or penalties	KO
				Conflict minerals	0%
				FDA warning letters	0%
		Quality	0%	Failures	0%
				Site relocation or closure	0%
		Financial stability country	0%	GDP growth rate	0%
				GDP per capita	0%
				Unemployment rate	0%
				Population below poverty line	0%
				Public debt	0%
				Inflation rate	0%
		Political situation country	0%	Political situation	0%
				Countrywide industrial disputes	0%
		Labor cost	0%	Labor cost	0%

Area Risk Score		Risk Score		Indicator Score	
		Logistics Performance	0%	Customs	0%
				International shipments	0%
				Logistics competence	0%
				Tracking & tracing	0%
				Timeliness	0%

Note. From *Riskmethods*

As a result of the many indicators, all suppliers are centered centrally between very low risk to medium risk (see Figure 6) and the exceptions automatically scored 100.

Figure 6

Illustration of supplier risk portfolio in Riskmethods
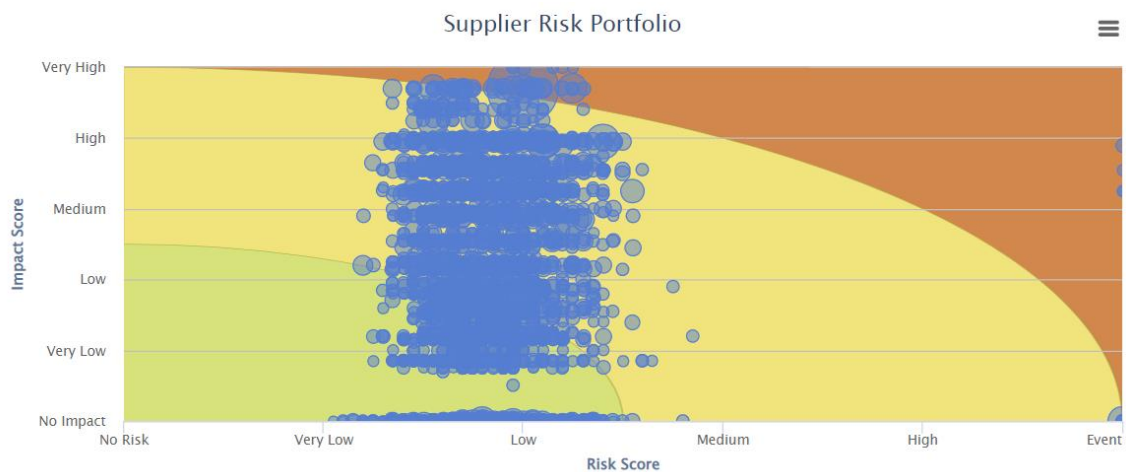
Note. From *Riskmethods*.

3.1.2 Impact Score

The Impact Score in Xylem is an assessment of supplier risk. The purpose of having the Impact Score is to monitor the progress of risk mitigations and continuously prioritize actions based on the changing risk trends. As shown in Figure 6, if multiple suppliers have similar impact scores, then suppliers with the highest risk score are prioritized for mitigation actions if resources are constrained.

The Impact Score is Xylem's internal assessment of the vulnerability of its supplier network. It is assigned a score of 15 – 100 (see Table 1 for a detailed scoring method). The higher the score, the

more vulnerable Xylem is against that supplier. The assessment is qualitative and is based on four criteria that are weighted:

- *Business risk:* revenue dependency on the supplier.

- *Supplier availability:* flexibility and availability of alternative suppliers to supply components and parts.

- *Time to recover (TTR):* the time needed to recover from a supply chain disruption of a supplier.

- *Supplier performance:* the qualitative evaluation of local suppliers on delivery, quality performance and cooperation.

Table 2 shows in detail how the Impact Score is derived along with the weightage in these criteria.

Table 2

Impact Score - Supplier Criticality Assessment.

DM Supplier criticality assessment - 2022				
	Description	**Answer options**	**Value**	**Weight**
1. Business Risk	How much of Xylem's revenue depends on this supplier?	< 1 MUSD (<1%)	20	30%
		1 to 10 MUSD (1-5%)	40	
		10 to 50 MUSD (5-10%)	60	
		50 to 100 MUSD (10-25%)	80	
		>100 MUSD (>25%)	100	
2. Supplier availability	How many suppliers are available and qualified to actively source from?	Multiple	10	25%
		Dual	20	
		Single	80	
		Sole	100	
		Customer designated / ETO	40	
3. Time to recovery (TTR)	How long does it take to re-establish supply after a disruption or establish an alternative sources?	< 1 month	20	25%
		1 to 3 month	40	
		3 to 6 months	60	
		6 to 12 months	80	
		> 12 months	100	
4. Supplier Performance	Local supplier score card evaluating on delivery and quality performance as well as cooperation	Outstanding	10	20%
		Good	20	
		Sufficient	40	
		Poor	60	
		Very poor	100	

Note. From Xylem.

The Impact Score is calculated by multiplying the answer value of each criterion by the weight.

Consider an example of supplier A with these criteria:

- Business Risk: USD 15 million (value = 60)

- Supplier Availability: Single (value = 80)

- Time to Recovery: 6 – 12 months (value = 80)

- Supplier Performance: Good (value = 20)

The Impact Score for Supplier A is total sum of weighted Business Risk, Supplier Availability, Time to Recovery and Supplier Performance:

$$(60 * 30\%) + (80 * 25\%) + (80 * 25\%) + (20 * 20\%) = 58$$

It is worth noting that if a supplier has a percent dependency where the business risk value is higher than the business risk value in absolute dollar value terms, the Impact Score assumes the highest between the two values. For example, if a supplier is identified with a revenue dependency of $15M USD but it is less than 5% of the business, it assumes a higher assigned value of 60 instead of 40.

Xylem has identified a few challenges with the current qualitative format the Impact Score is evaluated.

1) For manufacturing sites that share the same supplier, the assigned value may be more meaningful to one site but not the other. This means that when a manufacturing site where the supplier is not strategic or important but has a high Impact Score, the site still must invest in the efforts and resources to mitigate potential risks, causing wastage.

2) In determining the Business Risk Value, the weight of total revenue impact versus the % contribution to the total revenue is hard to determine. If a supplier has a revenue impact estimated at USD 30 million, but the % to the total revenue is only 5%, should the Business Risk value be 40 or 60 (refer to Table 2)? Currently, it defaults to the highest value. The clarity around measuring risk on a product or site level is not straight forward here.

3) There is no direct link between Xylem's revenue to the product components used to assemble a finished product. In other words, the supplier's business risk is the same value across manufacturing sites that share the same supplier.

3.2 The difference between Revenue at Risk and Business Risk value

As mentioned earlier, the definition of this new metric Revenue at Risk at the point of this capstone's undertaking was not clearly defined. It is a new measure that Xylem has been working on introducing in management meetings to provide a high-level management overview of risk levels per profit center. Based on the available documents from Xylem, the definition of this value is intended to quantify the progress of mitigation actions rather than providing exact absolute revenue that is genuinely at risk. The way Revenue at Risk is calculated is expressed below:

$$Revenue\ at\ Risk = Historical\ revenue\ of\ business\ unit * \frac{Impact\ Score}{100} * \frac{Risk\ Score}{100}$$

Even though Xylem clarified that it is not related in direct revenue terms, the metric can be easily misinterpreted.

Business Risk value on the other hand, is a value that is measured as part of the Impact Score criteria scoring. This parameter is about the supplier's impact on Xylem's revenue. In other words, it is the revenue at risk in Xylem by supplier.

The difference between these two metrics without understanding the context can be confusing. Revenue at Risk was developed because there were limitations to how the Risk Score and Impact Score could be reaggregated from a supplier level to a profit center level. The way the current Impact Score is structured in its calculation cannot be reaggregated from a supplier level to a profit center level. Xylem did not link the Business Risk value to the products that the suppliers supply parts to.

This is where the capstone offers a methodology to make that link that can be robust to enable different views of business risk in the company.

3.3   Summary

While Xylem's risk identification and assessment framework serves as a good foundation to monitor risks and prioritize mitigation plans, the framework does not consider the complexity of Xylem's supply chain. In the risk identification stage, Xylem does not consider the impact of one supplier on different sites. Each site receives the same impact score for one supplier regardless of the amount of spending or product complexity. It was confirmed in an interview with Xylem that the impact score of a supplier that supplies multiple manufacturing sites may not represent the same level of risk in each site that the supplier supplies to.

Therefore, in both Risk Score and Impact Score, opportunities to improve the scoring methods are clear. In this capstone, the focus area is to improve the valuation of business risk that represents the actual revenue of the finished product produced at a manufacturing site. The results of the new process to identify business risk are then compared to the current business risk value that is used as input to the Impact Score.

In Chapter 5, the findings from the new method compared to the current method are discussed. A brief discussion of complementary application in strategic procurement sourcing is discussed as well.

Chapter 4

4. Methodology

The process of identifying risks is crucial in risk management as it helps decision-makers become aware of potential uncertainties and manage them proactively. To choose appropriate management actions for identified risk factors, risk assessment and prioritization must be performed by considering subjective probability, past experiences, and the potential consequences from the company's perspective as different events may have varied impacts on companies. Actions are planned and executed thereafter. Some examples of actions are risk transfer, risk-taking, risk elimination, risk reduction, or further analysis on the identified risks. Finally, the risk status of a company and its environment is in a constant state of flux. Therefore, all the actions to counter the identified risks, and developing trends that may lead to risks should be monitored.

Identifying and assessing risk has had a broad coverage of definition in the past 20 years of research. Different approaches and risk management strategies were theorized and modelled based on how supply chain risks are classified and categorized. The main theme that connects the various approaches is the simple notion of supply chain risk as the likelihood of an event happening that will result in a negative impact on supply chain performance.

The main objective of the capstone is to improve the process framework of Xylem's Supplier Risk Management Program by presenting an improved way to calculate Business Risk value. One of the main challenges is the disparate data from a fragmented IT landscape. The financial data (actual revenue), product hierarchy, supplier, and risk data all sit in different databases.

This chapter introduces the process steps for cleaning and merging different data sources, calculating the Business Risk value, and revising the Impact Score. The study focuses on the data from one large and complex site in Sweden, which served as a pilot test site in this capstone. Python is the main program used to clean and merge different data sources.

One of the project team's goals was to build a simple start-up code that can be replicated easily to other sites in Xylem. Considerations were given to the variety of data available in this complex site versus the minimum viable information needed to generate a list of Business Risk value per supplier per site, because each site have different database structures (due to different ERP systems). Hence, the startup code is a simple and minimum viable product that can be used in all sites to generate a list of Business Risk value per supplier by site. For data visualization, the starter code is designed with an output that can be easily populated into Power BI. In summary, Xylem will need to only populate 4 Excel templates, which then feeds into the Python start up code, where the output is then put into Power BI (Figure 7).

**Figure 7**

From site data to Power BI
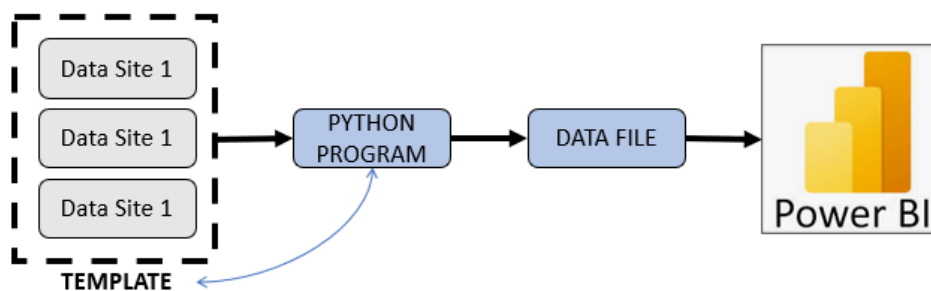
4.1   Program Input

The different datasets exist in various databases and are not connected in Xylem's landscape. A python program is written specifically to establish the connection and relationship between suppliers, parts, components, finished goods, scores and revenue. For all the documents below, a template format has been created with indications of the mandatory columns and the optional columns. The datasets merged are illustrated in Figure 8.

Figure 8

List of datasets
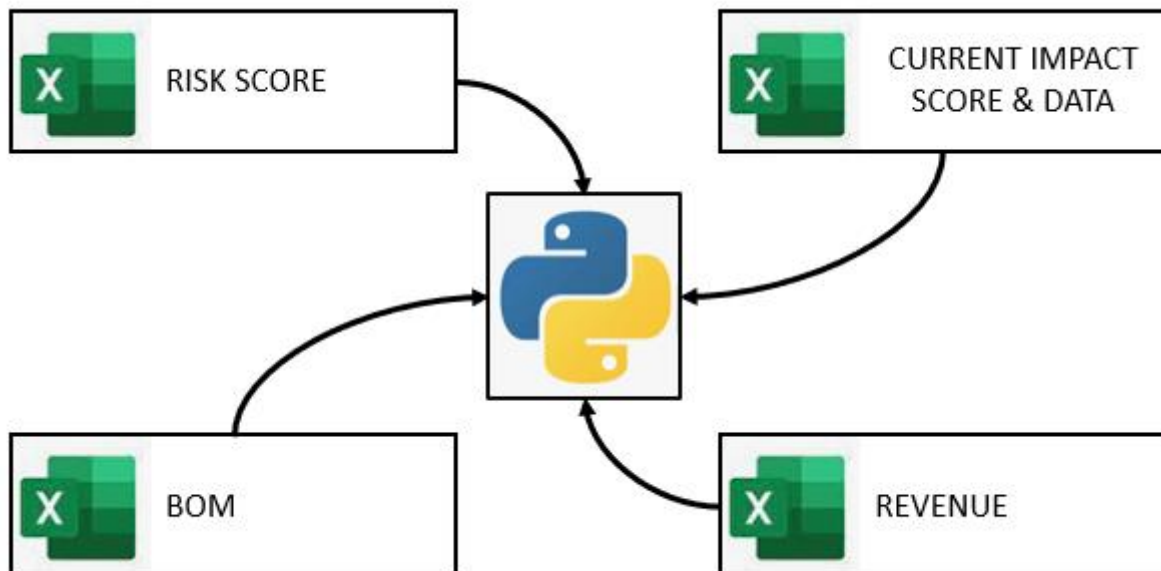
Description of source data:

1. BOM: Site's Bill of Material

    This is the site's localized data stored in MS Access. It has 94,339 rows for each part number associated to a finish good model with preferred suppliers.

2. RISK SCORE: Supplier risk score data from *Riskmethods*.

   This data is extracted from *Riskmethods* platform. The data is dynamic. The purpose of programming the score into the capstone's data frame is to perform a sanity check, and to establish an overview of the current risk level for this site.

3. REVENUE: Revenue of finished goods sold

   The Finance department provided the list of all finished goods items in the site and their annual revenue, expressed in Euros.

4. CURRENT IMPACT SCORE & DATA: Central Risk Team repository of Impact Score

   The Central Risk Team keeps a repository of the total supplier list from the Supplier Risk Management Program with the criteria values of the Impact Score and Risk Score. This dataset is used exclusively to perform a comparative analysis between the capstone's Business Risk value mapping versus the Central Risk Team's value.

These different source datasets are merged, but encountered data quality issue where the supplier names were not consistent throughout the different data datasets (~70% not matching), and the supplier ID also did not resolve the issue. Therefore, a 5th dataset is established to match the names instead of performing data cleaning within Python for pragmatic reasons that similar issues will be encountered when scaling this to other sites. Some supplier name match had to be performed manually and clarified with the company.

4.2   Program Run

The datasets that are merged demonstrated the connection of suppliers/parts and components to a finished good product regardless of the procurement spend cost. The main objective is to calculate the maximum lost revenue per supplier. The mitigation actions to reduce the Business Risk value such as supplier switching is factored in when calculating the overall Impact Score.

Figure 9 illustrates this. Using the illustration below, Supplier 1 is said to have 12% involvement at the site's revenue ($350/$2830 = 0.12). Therefore, if Supplier 1 disrupts the flow of Part no. 1, Finished Good 1 will not be able to be produced and risks a sales opportunity of $350 for Finished Good 1. Supplier 1 is then assigned a Business Risk value of 12. Another example from the illustration, Supplier 3 supplies Part no. 4 that is used in Finished Goods 1, 2 and 4. Disruption by Supplier 3 is deemed as having very high impact on business as it will affect 96% of the total revenue generated at site. The Business Risk value assigned to Supplier 3 is 96.

Figure 9

An illustration of datasets that are merged.
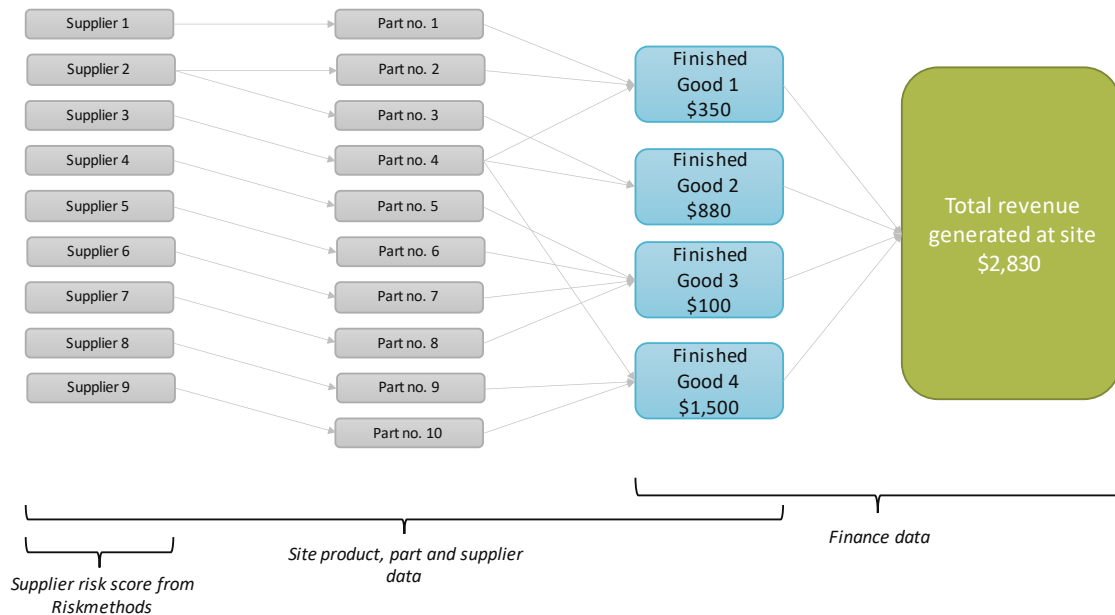
4.3 Program Output

The output of the Python program expresses the risk identification and risk assessment stages of the Supplier Risk Management Program of one site. An Excel output is used for data visualization in Power BI.

Risk Identification

Xylem has a defined threshold for low, medium, and high risk. High risk score is >70, medium risk score is >40, and low risk score is <40. Taking the current risk scores from *Riskmethods,* a quick overview of low to high-risk suppliers is counted (see Figure 10, left chart). The new perspective for the local manufacturing site is the ability to also flag which finished goods that are identified as low to high risk (see Figure 10, right chart). If a supplier from *Riskmethods* is flagged as high risk,

and that supplier is supplying the part to the specific finished good item, then it is flagged as the finished good item having a high risk.

Figure 10

Risk distribution on random day
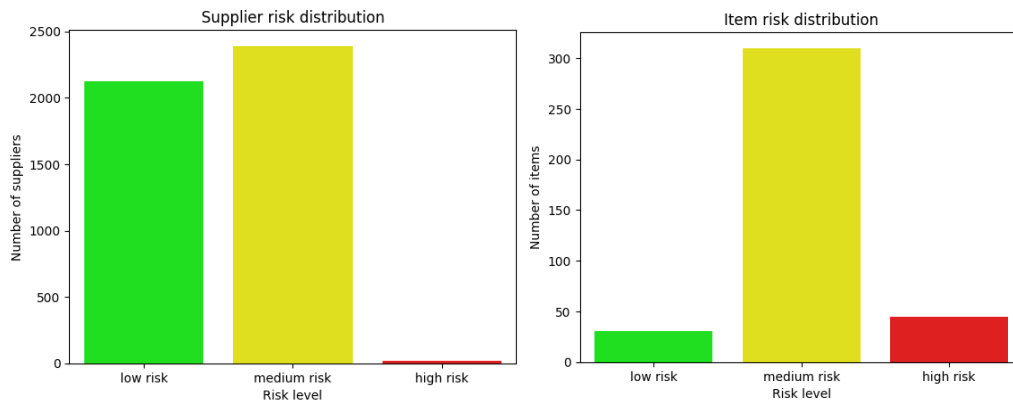
Risk Assessment

Knowing which finished goods are high risk, the revenue impact is identified per finished goods. Because the parts from the finished good at risk relate to the supplying suppliers, the revenue impact of the suppliers is identified. As such, for the suppliers that are identified as high risk, the business can understand the revenue impact specifically because it is traceable to the finished goods. The Business Risk value is mapped to the supplier.

It is worth noting that the Risk Assessment exercise of Business Risk value mapping per supplier is useful to identify the vulnerabilities in the supply chain, regardless of the risk level of the supplier.

4.4 Calculation of Revised Business Risk Value and Impact Score

A revised Business Risk Value is calculated after processing the data by merging and cleaning the different data sources. The revised business risk value is derived based on the actual linked revenue

involvement from 0 – 100 of a supplier that supplies the parts and components to the finished good. Going back to the illustration in Figure 9, Supplier 1 which has a 12% involvement at the site's revenue generates a business risk value of 12, while Supplier 3 which has a 96% involvement at the site's revenue generates a Business Risk value of 96.

Based on the revised Business Risk value calculation per supplier, a revised Impact Score is calculated, with the assumption that all other elements to calculate the impact score remain the same. The comparison of the revised values against the original values is visualized through Power BI. With this new method, it is still possible for the Central Risk Team to establish a global view on suppliers Business Risk value in the future, based on the total accumulative revenue across all sites, or a weighted average based on revenue of each site. This method provides a structured, objective, and transparent way of capturing Business Risk value that is easily understandable.

Chapter 5

5. Results and Discussion

The results and discussion are based on one manufacturing site in Sweden selected by Xylem. When combining the different data sources (one from the manufacturing site, one from the Finance department, and one from the Central Risk Team), of the 286 suppliers that are supplying the manufacturing site, 156 of them are not found in the Central Risk Team's data. This was not a surprise because only half of the entire supplier base is officially on the Supplier Risk Management Program.

The missing data does not affect the results of this study. Rather, it highlights the challenges in managing and monitoring a large supplier base with limited resources. Furthermore, to be able to manage and monitor supplier risks, detailed information with good data quality is required, this is not usually readily available. Table 3 shows that 8 suppliers that are not monitored globally have a high Business Risk value, which means that each of these suppliers if disrupted, will affect at least 80% of the revenue generated.

Table 3

Business Risk Value of suppliers not monitored globally.

Business Risk Value Range	No. of Suppliers
80 -100	4
60 - 80	4
40 - 60	6
20 - 40	12
0 - 20	130
Total	**156**

In this chapter, the new business risk value is compared to the current business risk value to draw insights about the meaning of these differences and future applications beyond risk management into sourcing strategies.

5.1   Descriptive Overview

In this section, we looked at the descriptive summary of the total suppliers that supply the manufacturing site, number of models produced, and the number of parts that go into assembling all

the models. Table 4 summarizes the manufacturing site's total number of suppliers, models, and parts. It is, without a doubt, a complex business operation with many potential risks.

Table 4

Overview of total suppliers, models produced and parts in assembly at the Sweden manufacturing site.

Total Suppliers	286
Total Models produced	386
Total Distinct Parts in assembly	13,005

At this manufacturing site, a total of 386 unique models are produced using 13,005 distinct parts. The simplest models require 48 distinct parts while the most complex has 535 distinct parts (see Figure 11). Summing up the total number of parts assembled into all 386 models equated to a total count of 94,339 parts. A metric to measure part standardization in manufacturing is a commonality index, which describes the number of parts that are used by more than one end-product. Since complexity drives risks, this metric is useful to understand the degree of manufacturing complexity. Specifically at this manufacturing site, there are 94,339/13,005 = 7.25 common parts shared amongst different models.

Figure 11

Number of parts per model.
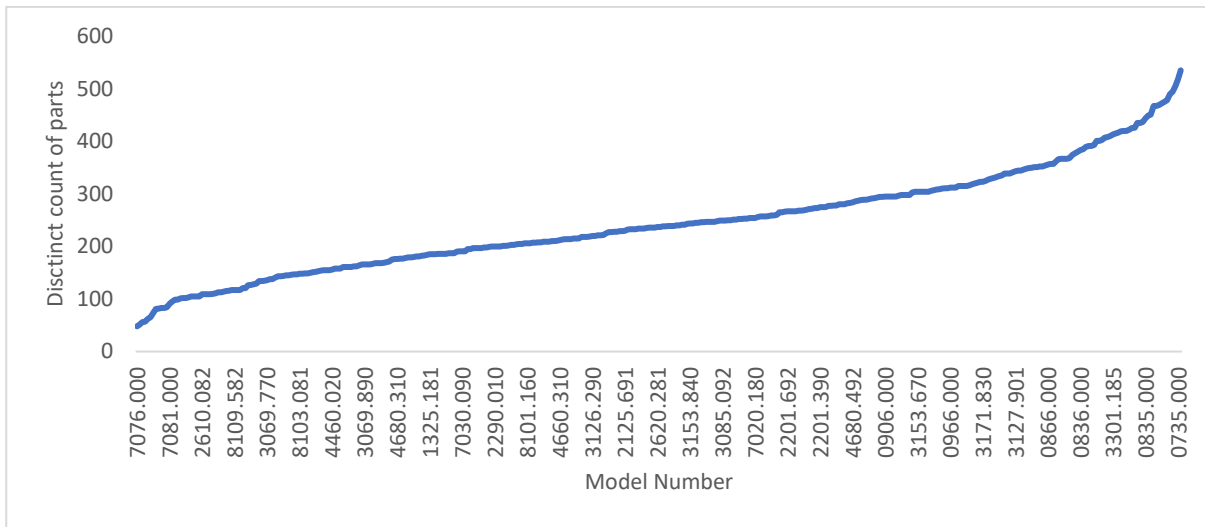
Part standardization is one of the key procurement strategies to leverage on volume and inventory

pooling purposes to reduce costs in manufacturing. The trade-off, however, is the business risk if

the parts are unique and only a handful of suppliers are supplying these parts. Table 5 represents the

top 10 parts that are used. Looking at the top 10 parts and corresponding to the main supplier for the

parts, four of the most common parts are not found in the global Supplier Risk Management

Program, and the three most common parts are single sourced, with one of them having a >12

month switch over if there is a disruption. As such, the takeaway from the top 10 results is that

business risk can be measured on commonality of parts in models when managing risks in the supply chain.

**Table 5**

Top 10 common parts at the manufacturing site.

Part Number	Number of Models	% of total models	Supplier Availability	Flexibility in Alternate Sourcing
6308500	331	86	NA	NA
902660	275	71	Single	6 – 12 months
901752	262	68	Single	> 12 months
822088	255	66	Multiple	3 – 6 months
834559	253	66	Multiple	3 – 6 months
941490	238	62	Single	6 – 12 months
903280	216	56	NA	NA
834262	216	56	NA	NA
6306800	211	55	NA	NA
4271300	209	54	Multiple	3 – 6 months

Finally, the most important aspect in business is the revenue generated. Each model has its own selling price and unit cost to manufacture. Understanding a model's revenue impact on the total revenue provides insights to business impact. Roughly 20% of the models deliver 80% of the revenue. Based on the illustration in Figure 12, each point represents a model with the number of

parts and the % contribution to total revenue. The top models that fall between first and third

quartile are top revenue generators, and the feature that is common amongst these models is that

they are complex products manufactured requiring many parts to manufacture the finished model.

Figure 12

Revenue contribution per model and count of parts
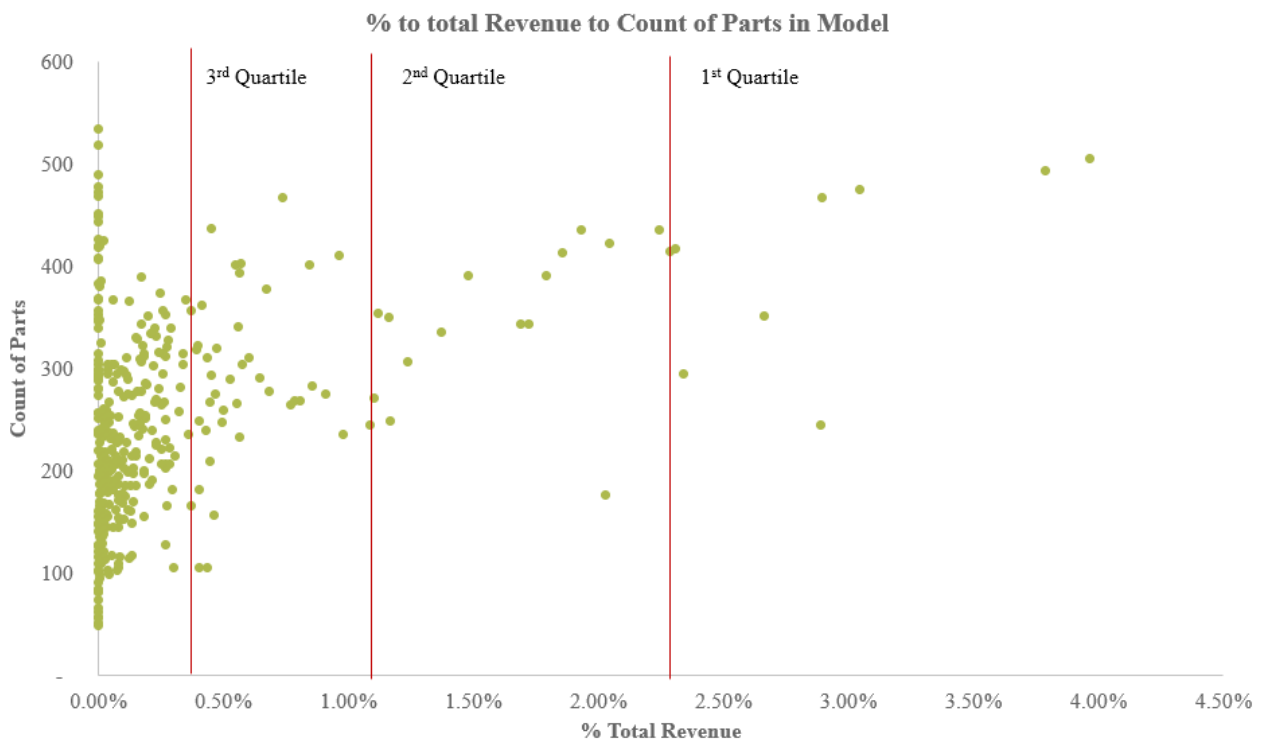
In summary, the complexity of manufacturing drives complexity which then influences the degree

of business risks. Even complexity reduction tactic such as parts standardization has its trade-off

when evaluating business risk impact. For the top common parts in the results, a further

investigation into the inventory policies and the single-sourcing decision is recommended to ensure

there are sufficient buffers in place to build resilience. Finally, another aspect in managing business

risk is to look at the revenue impact of the top revenue generating models. These top revenue

generating models are typically complex to manufacture that require many different parts. Here, the

recommendation is to ensure the top products are regularly monitored for parts where suppliers have a high Impact Score. The Impact Score will highlight where the vulnerabilities are, and the goal is to address the vulnerabilities.

5.2   New Business Risk Value

The new Business Risk value generated from the program output was compared to the original Business Risk value. The delta values between the new and original values were plotted into a histogram plot to identify the number of suppliers in the various delta value buckets (see Figure 10).

$$Business\ Risk\ \Delta = new\ Business\ Risk\ value - old\ Business\ Risk\ value$$

Out of the number of suppliers with an old Business Risk value, six have delta values >0, while most are <0. The results suggest that the suppliers where values are >0 are undervalued by Xylem. To put it into business context, these suppliers have high a revenue impact based on the parts they are supplying for manufacturing of various models at the site. But because their original Business Risk value was valued low, these suppliers may have been overlooked. When reviewing the details spending and sourcing strategies for these suppliers (Table 6), vulnerabilities are showing, i.e., single sourcing and flexibility to switch of >6 months.

Figure 13

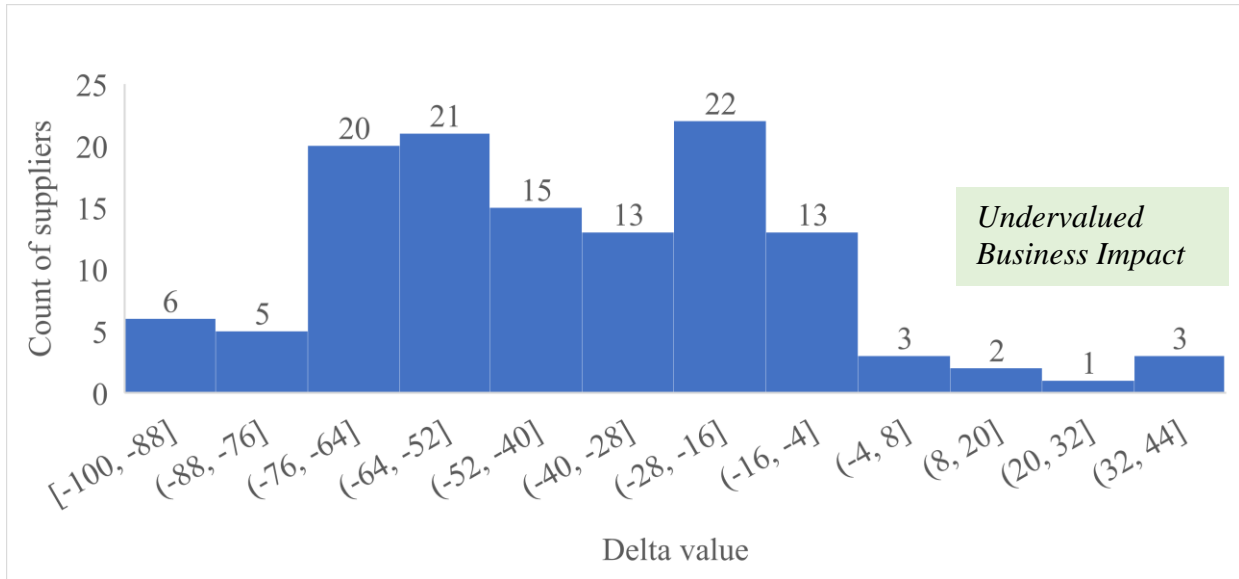*Histogram plot of suppliers' Business Risk delta*

Table 6

Suppliers with positive delta values.

Supplier	% Spend to total spend	New Business risk value	Old Business risk value	Delta value	Supplier Availability	Flexibility in alternate sourcing
SH	0.05	64	20	44	Multiple	> 12 months
GE	0.20	60	20	40	Multiple	> 12 months
SY	0.09	78	40	38	Single	6 to 12 months
RO	1.29	50	20	30	Multiple	3 to 6 months
TE	0.89	40	20	20	Single	6 to 12 months
SY2	0.03	34	20	14	Multiple	6 to 12 months

Furthermore, with spending that is <1.30% of the total spend of this site, these suppliers that has a revenue impact of >34% can quickly escalate if any of these suppliers are disrupted (subject to inventory policies maintained at both supplier and Xylem and other time-to-survive mechanisms). In our view, these suppliers were in Xylem's blind spot.

Another observation when comparing the Business Risk values is the tendency to label many suppliers with a high business risk in the old method. 73% of total spending are allocated with a Business Risk value range >80 (see Table 7). In other words, there is an underlying assumption that spending is in direct proportion to revenue at risk. With the new method by mapping parts, suppliers to models and revenue, the actual high revenue at risk suppliers only account for 28% of the spend. From a business context, dedicating limited resources to managing a large pool of suppliers because many of the suppliers having a Business Risk value >80 becomes challenging to manage. And even if it is possible to do so, there is a lot of efforts and resources being focused on areas that is not of great concern.

Table 7

% of total spend to Business Risk Value per range and the numbers of suppliers.

Business Risk Value Range	% Total spend		Number of suppliers	
	New	Old	New	Old
0 - 20	31%	6%	65	23
21 - 40	12%	3%	19	7
41 - 60	18%	8%	15	16
61 - 80	12%	9%	16	16
81 - 100	28%	73%	15	68

In summary, the value difference between the old and new Business Risk value is driven by supplier spend. The old method shows that suppliers that constitute high spend % tend to be categorized as high business risk while low spend % are categorized as low business risk. Simchi-Levi demonstrated that profits have no correlation to how much Ford spends at the supplier (Simchi-Levi et al., 2015).
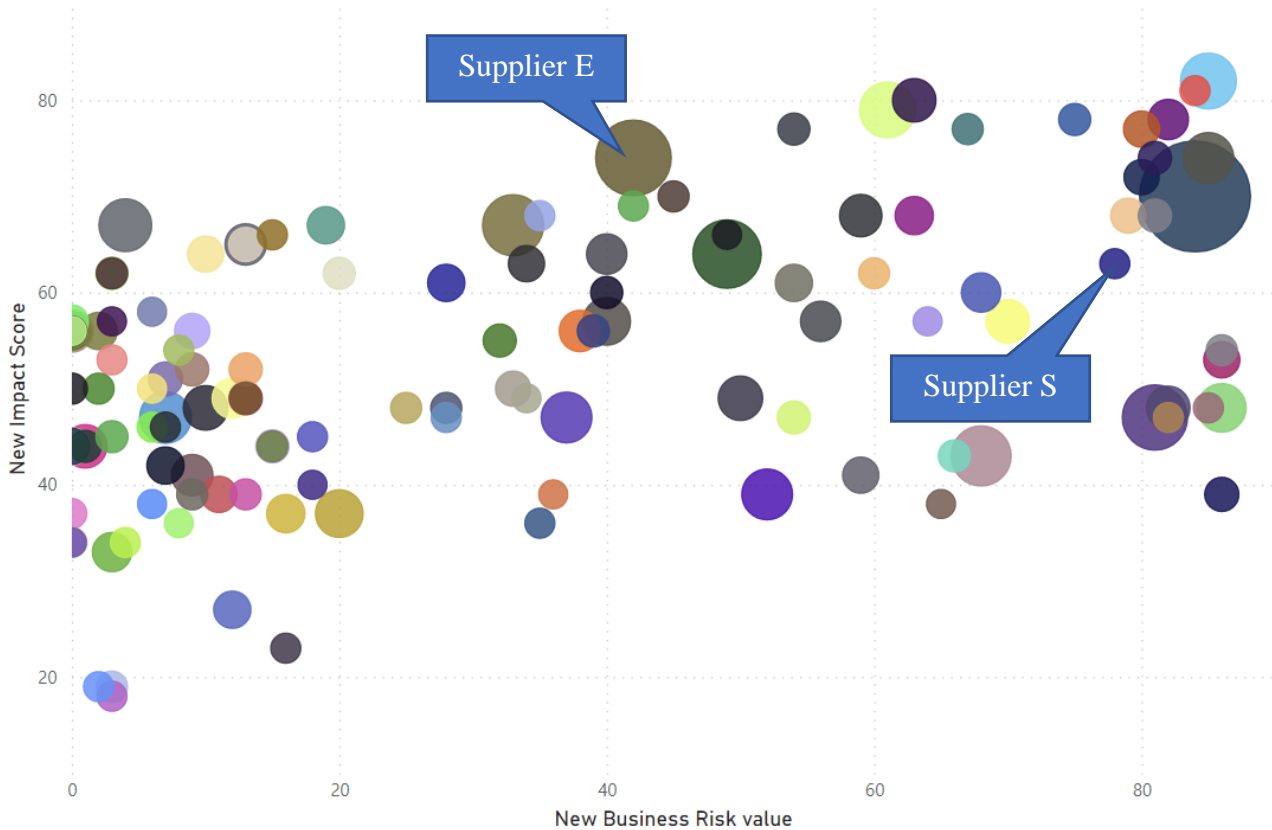
5.3   New Impact Score

To recap, the Impact Score refers to the level of impact that a supplier can have on the supply chain based on Business Risk, supplier availability, TTR and supplier performance. With the new Business Risk value, the Impact Score is also adjusted, while maintaining the same weight distribution of 35%. Figures 14 and 15 illustrate the difference between new and old Business Risk value and Impact Score. The new method showcases a score with a continuous range while the old

method was discrete. The continuous range of the new method is based on the way the Business

Risk value is mapped, which is a continuous 0 - 100% revenue contribution of a supplier to the total

revenue generated, while the old method was focused on assigning a discrete value of 0, 20, 40, 60,

80, and 100 for each supplier.

Figure 14 provides a robust overview of the revenue at risk (Business Risk value) and the mitigation

actions that affect the three other criteria (supplier availability, TTR and supplier relationship and

performance). In this view compared to the old Business Risk value, a clear prioritization matrix

can be formed, and a clear target can be derived. For example, to reduce Impact Score to <70 for all

suppliers, starting from the highest Business Risk value.

Figure 14

Scatterplot of new Impact Score vs Business Risk value (bubble size = spend)

Another point to on the difference of Impact Score change after the Business Risk is recalibrated to actual revenue at risk, is some suppliers that do not have a high business impact are moved down the Impact Score range, while some suppliers has a real high business impact, and thus moved up the Impact Score range (see the examples of Supplier S and Supplier E in Figure 14 and 15). These changes will influence risk mitigation decisions, where priority would be given to Supplier S over Supplier E in the new scoring method. Overinvesting in risk is not an issue for Supplier E, but redundancy can be wasteful. Underinvesting in risk, however, can have other severe consequences apart from financial impact. Brand reputation and image, customer experience, etc. are just other negative consequences of supply chain disruption.

Figure 15

*Scatterplot of old Impact Score vs Business Risk value (bubble size = spend)*
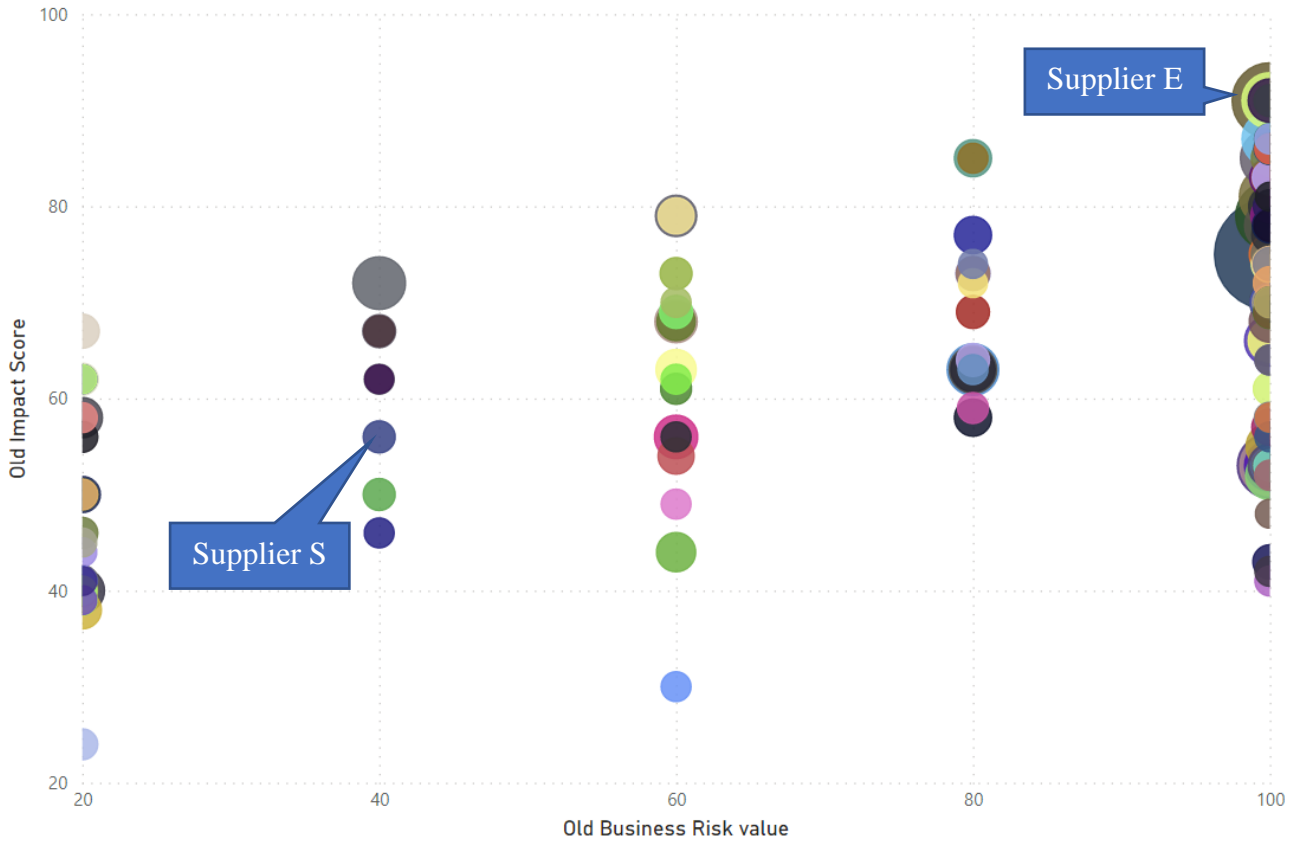
Finally, the recalibrated Impact Score with the new Business Risk Value shows that many of the suppliers now have a lower Impact Score compared to the old Impact Score (Figure 16). The 35% weightage applied to Business Risk value when calculating the Impact Score has a significant influence. The distribution of suppliers across the Impact Score ranges are evenly distributed compared to the old one which is skewed to the left.

When the results of the recalibrated Impact Score was presented to the Global Director of Risk Management, it validated his views about the heightened Impact Score with the old method. With

the recalibrated scores, the number of high business risk impact suppliers was reduced and provided better prioritization and focus to the areas of real vulnerabilities were.

Figure 16

Number of Suppliers per Impact Score Range (New and Old)
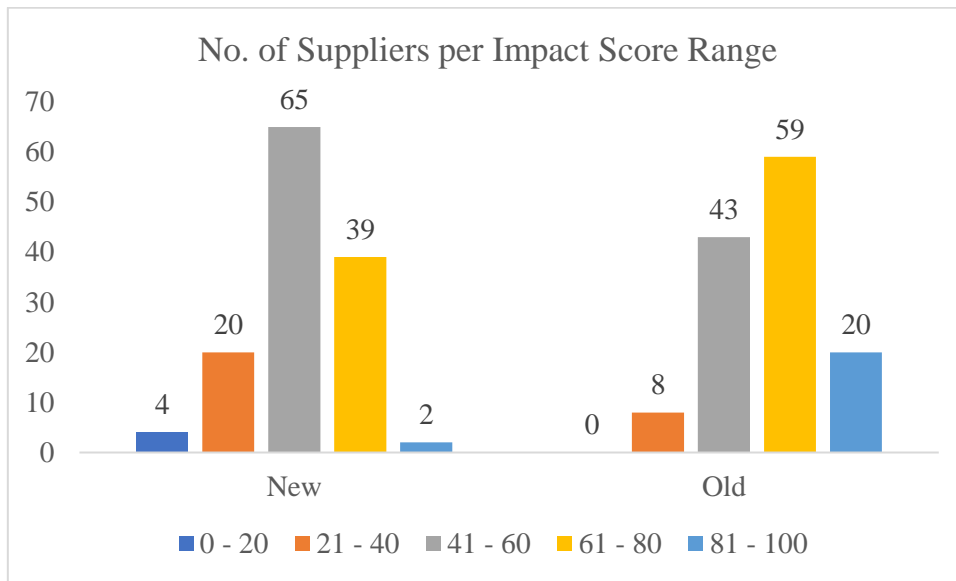
In terms of total spend to Impact Score, there is no strong inference as compared to Business Risk value. This is because the Impact Score has other weighted criteria that influence the scoring, and it is not related directly to procurement spend. Rather, it is influenced by the Business Risk value where mitigation actions are taken based on the risk impact to the business.

5.4   Discussion

The most important revelation in this capstone is that procurement spend is not correlated to revenue or profits of a company. In Xylem's case, it is evident that the old Business Risk value is linked to supplier spend, where 73% of the procurement spend is assigned a Business Risk value >80. This capstone then mapped the actual revenue and created the new Business Risk value and demonstrated that only 28% of the total supplier spend has a revenue impact of >80. This is not

unique to the company: Simchi-Levi et al. (2015) pointed out a similar insight in their research on Ford. One potential reason that Xylem defaults into using procurement spend as a proxy measure for business risk impact can potentially be justified by the fact that there is limited data availability, and the data landscape is fragmented. When speaking to Xylem, they mentioned that many manufacturing sites operates on different ERP system, making it challenging to build this business risk impact quantification model. Furthermore, it was also mentioned that there was a similar project in Xylem to attempt to develop the same model as this capstone back in 2019 but failed.

The second point to highlight in this capstone is the fact that the Supplier Risk Management Program is run on a centralized level. At a centralized level, greater coordination can be achieved, especially when there are global strategic suppliers. The trade-off is the granularity of supplier risk levels and impact at a site level. Xylem's Central Risk Team relies on local manufacturing sites to provide input to the Impact Score. When all suppliers are aggregated into a global pool of suppliers, the small and local suppliers have a smaller footprint of procurement spend, and low Business Risk value compared to regional and global suppliers. These smaller suppliers can have a high revenue impact and can be a local common part supplier that has a low unit cost but ends up overlooked. As we have also seen in the capstone, 4 suppliers were not found in the global Supplier Risk Management Program, and 6 suppliers had a Business Risk value that is lower than the actual revenue impact. They are considered "hidden risks" in Xylem's supply chain, and the recommendation should be to assess further actions needed for these suppliers.

Third, the perspective to keep in mind in risk management is that when everything becomes a priority to manage, then nothing is a priority. In the old Business Risk value, 52% of the total supplier base is flagged as high Business Risk (>80), compared to 12% in the new Business Risk

value. We discussed with the Risk Management team that the previous rules to estimate the Business Risk were maybe not fully understood by the people rating it on site, leading them to potentially over evaluate the score to "protect" themselves. We also considered that the previous rules where not a good fit for all sites (as they have small and large manufacturing sites). The new Business Risk value creates better clarity and captures the revenue impact objectively. This allows for better decision making on designing mitigation strategies that will contribute to lowering the Impact Score. In the various discussions with Xylem, an ongoing action log of mitigation actions with corresponding investment costs (CAPEX) is regularly reviewed. With the new lower Impact Score, these investments should be re-evaluated and redistributed to areas where supply chain vulnerabilities have been identified which were overlooked in the old Impact Score method. In other words, having actual revenue impact allows the business to compare the risk and rewards in accepting or mitigating risks.

Lastly, the quantification method adopted in this capstone to calculate Business Risk value provides the opportunity to extend the usage into other areas of Procurement outside of Risk Management. Since Business Risk value is defined as the maximum profit impact of Xylem in the event of a supplier disruption, and there is the Risk Score captured using *Riskmethods*, Xylem can utilize this information to evaluate their sourcing strategy using Kraljic's Supply Risk/Profit Impact matrix (Kraljic, 1983).

Figure 17 is an example applying actual data from Xylem's Risk Score (Supply Risk) and Business Risk value (Profit Impact) with no further manipulation of data. On the surface, it shows clearly that supplier spend does not correlate strongly to either profit impact or supply risk. The majority of its supplier base falls into the non-critical quadrant. However, this needs to be further assessed as the

Risk Score as highlighted earlier is based on 95 different weighted risk indicators that makes for the interpretation of risk level diluted. Nonetheless, the application of Business Risk value is clear. The matrix can be further developed to look at the different supplier categories and assess the strategic nature of the categories to Xylem's business.

Figure 17

Profit Impact versus Supply Risk of Xylem's supplier using Kraljic's Matrix (bubble size = spend).
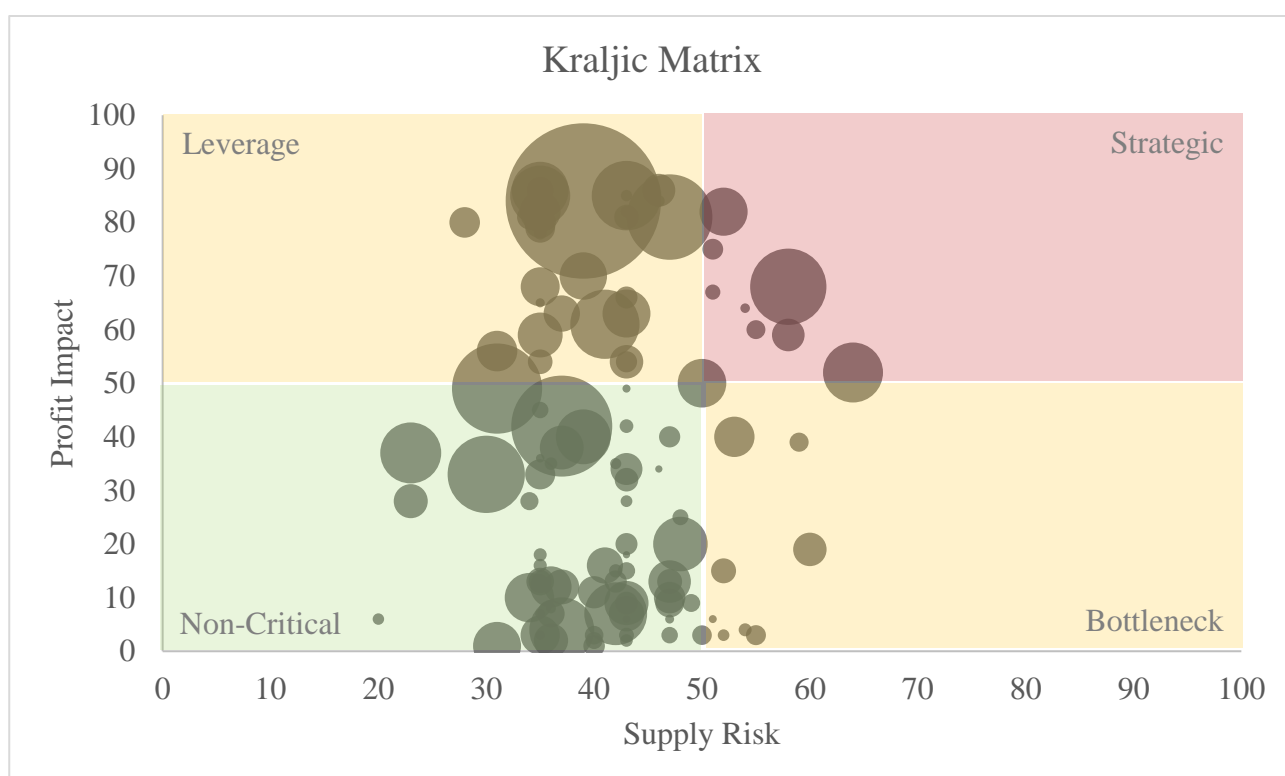
5.5   Recommendations

This capstone proposes a few recommendations for Xylem to continue their exploration and maturity of their Supplier Risk Management Program. The program itself is an established and well governed and inclusive framework to bring multiple stakeholders to address future supply chain risks and challenges. In the immediate short term, there were a few suppliers that have been

highlighted that were not on the global Supplier Risk Management program and the Business Risk value was undervalued. These suppliers should be reviewed to ensure there are sufficient mitigation actions to build resilience in the supply chain.

In the long term, we highly recommend that the Business Risk value mapping be scaled up across Xylem's sites with our program tool. With actual parts, suppliers, products, and revenue mapped, the output can be used in various situations or contexts such as:

- evaluating business case that requires investments to the revenue generated,

- using it in the context of strategic sourcing management,

- using it as the common business language that all stakeholders outside of procurement understand the importance of risk management and to get buy-in

- using it to assess risk in different views such as by profit centre, product category, manufacturing regions, etc.

Apart from scaling up, other recommendations to improve the overall program further are as below.

Recommendation 1: Continue to expand the global database to include smaller suppliers that are currently not in the Supplier Risk Management Program. This is an important factor, considering that this capstone has found some suppliers that are not being actively monitored. Data availability has been the main challenge to collect external supplier information and risk information, which explains the reason only 50% of the total Tier-1 suppliers are mapped. If data availability is a genuine challenge, we recommend that as a minimum that Business Risk value is mapped and to dedicate resource to prioritize suppliers that has a high revenue impact. On top of

this, the creation of a name convention by supplier on all ERP, or a common supplier number would be ideal.

Recommendation 2: Consider adding Time-to-Survive (TTS) to complement TTR. One of the other time-related concepts to assess supply chain risk is TTS. This added measure will allow Xylem to capture actual time of financial impact on the business. For example, if TTR > TTS, there will be a delayed time before the business experience disruption. On the flip side if TTS > TTR, then the impact to business is 0. The most common way to establish TTS is to look at the inventory stock levels on-hand and in the pipeline. Inventory management is one of the operational mitigation actions that can be taken to build resilience in the supply chain. Information on inventory levels should be available in the company as they are an essential part of the S&OP process and capacity planning.

5.6   Limitations

In its review of Business Risk value, this capstone has a few limitations.

Limitation 1: Criticality of the product substitution of their finished good is not considered here when mapping Business Risk value. The capstone does not factor in any finished model substitution should one model become out-of-stock due to supply chain disruption.

Limitation 2: The complexity of multiple supplier setup for component parts. The capstone acknowledges that some parts have multiple sourcing agreements in place, but this was not factored in. The main reason is that not all data of the alternative supplier was available. The team performed

a sanity check on the BOM dataset for the test site, and it showed only one part number linked to one supplier.

Limitation 3: The complexity of backup supplier. In the current methodology, backup suppliers are not considered if a disruption occurs with the primary supplier. The data availability is limited. While this is important to factor in, but because the switching of suppliers takes time, it is more important to understand the Time-to-Survive (TTS) metric first.

Chapter 6

6. Conclusion

Globally, COVID-19 has reshaped the world and revealed the vulnerabilities of the supply chain systems we have designed. Prior to COVID-19, supply chain disruptions had local or regional impacts such as fires and natural disasters, which still allowed room for sourcing alternatives, but not during COVID-19. Therefore, companies must take firmer actions in taking Supply Chain Risk Management seriously to build resilience in the face of future unknown disruptions that are not possible to anticipate.

However, measuring risk and its impact is not straightforward because of the challenges that companies face such as data availability, interpretation of the many types of risks, and a complex product-supplier network. The challenge that Xylem posed to the capstone team was to quantify the impact of risk using revenue as a measure. They use a financial impact measure today, but it has its limitations. Based on the objectives the capstone team identified, we built a Python program to measure the impact of risk by supplier, based on the amount of revenue the supplier has an impact on, called Business Risk value.

The approach we took was to map the parts, suppliers, models, and revenue, which is structured and objective and can be standardized across the different sites. In contrast, Xylem's approach is based on qualitative and "quantitative" estimates of revenue impact, which is based on the local manufacturing site input. It lacks transparency regarding how the revenue impact was derived, and there is no standardization of the process measure.

Our observation when comparing the new Business Risk value to the old Business Risk value is that procurement spending is not correlated to the revenue impact of the company. This observation has allowed us to capture suppliers whose actual Business Risk value is high, to be detected; while in the old method, their Business Risk value was not high because their procurement spending was very low. Likewise, for suppliers that have a high procurement spend, the Business Risk value is high in the old method. These suppliers are prioritized with resources and efforts, of which the cost of mitigating these risks may not add up to the actual revenue impact and creates unnecessary redundancy in the supply chain.

We also found that with a structured way to capture the Business Risk value in Xylem, its output can be applied outside of the scope of risk management. In strategic procurement sourcing, having a supply risk/profit impact portfolio of all suppliers is an important aspect in setting up effective contract agreements and supplier engagement programs. Risk management then becomes an integral part of the strategic procurement sourcing process, where finer details such as lead time, inventory agreements, etc. can be agreed with better transparency to build resiliency in the supply chain.

Finally, we acknowledge that in business, resources dedicated to risk management are limited. Therefore, our recommendation to Xylem in maturing the Supplier Risk Management Program is to focus on expanding the global database to include smaller suppliers that are currently not in the program, with the emphasis to have at least the Business Risk value mapped throughout the supply chain in Xylem. Because risk is unpredictable and uncontrollable, the way to be prepared for disruptions is to understand where the vulnerabilities are. Suppliers with high Business Risk values regardless of the state of the Risk Score provide adequate insights into mitigation actions that need

to be taken. Linking to understanding vulnerabilities, our other recommendation to Xylem is to map Time-to-Survive (TTS). This measure will factor the time to impact for a disruption, which up until now, has not been factored in, and currently assumes that a disruption will immediately result in revenue losses.

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