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ARTIFICIAL INTELLIGENCE & MACHINE LEARNING: SUPPLY CHAIN RISK
MANAGEMENT

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ABSTRACT

The resurgence of Artificial Intelligence (AI) and Machine Learning (ML) research has increased technological innovation. The field of Supply Chain Risk Management (SCRM) benefits from the increase in AI and ML tools and solutions, which provides a means to better identify, assess, mitigate, and manage supply chain risks. As organizations broaden and globalize their supply chains, they are introduced to new supply chain risks. Different forms of risks occur depending on the structure of an organization's supply chain. As the types of risks vary, the solutions implemented to identify and manage risk will also vary. Currently, on the market, there are tools specialized in providing solutions to address risks in different segments of the supply chain. AI and ML can help organizations reshape their SCRM processes when used properly. The use of AI and ML may be a solution that works for one organization but may fail at another organization. This thesis analyzes the impact of AI and ML on SCRM by first defining AI, ML, and SCRM. The thesis will identify findings from interviews and research on these technologies and provide current tools and solutions available on the market.

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Chapter 1

Introduction

The growing complexity of supply chains has led to an increase in the need for Supply Chain Risk Management (SCRM). This increase in supply chain risk demands for new and innovative ways to address them. The introduction of AI and Machine Learning in the supply chain has resulted in new programs and tools for assessing and managing risks. The adoption of Artificial Intelligence (AI) and Machine Learning (ML) technologies are investments made by companies to enhance their supply chain operations, in addition to predicting and preventing unforeseen supply chain vulnerabilities and disruptions. AI and ML have also received increased attention within the supply chain of the public sector for mitigating risks. The increase in computing power and availability of data provides companies the opportunity to utilize AI and ML technologies for managing their supply chain risks. SCRM aims to shield companies from disruptions in their supply chains by predicting the occurrence of disruptions, analyzing the impacts, and mitigating the adverse effects. Having a stable and reliable supply chain results in company success.

AI-based solutions have provided benefits to companies like Greenworks Tools, a leader in battery-powered outdoor power tools. Greenworks Tools used IBM's Sterling Business Network software to support its global availability and compliance with data laws across the globe (IBM – Watson Supply Chain, n.d.). It eliminates IT risks and product risks in their supply chain. The implementation of the software has resulted in IT cost savings and increased their consumers' visibility of their products.

Managing supply chain risks is also an important topic within the public sector. The government faces many supply chain risks, which makes it difficult for them to manage those risks in a cost-effective manner. Additionally, the government faces a lack of robust processes for identifying and managing supply chain risks. Government organizations struggle with cybersecurity breaches which often result in the loss of critical intellectual property. Supplier bankruptcy, late deliveries, climate issues, and quality issues are a few more examples of risks that the public sector faces. These similar risks are faced by the private sector. The practices of the private sector can serve as a foundation for SCRM in the public sector. The best-in-class tools and methods used by the private sector may be beneficial for addressing risk in the public sector's supply chain. This thesis is dedicated to identifying AI and ML technologies, currently implemented or researched by the private sector, that can be adopted by the public sector to manage supply chain risks.

The research for this thesis is synthesized from various sources including articles, journals, websites, and phone interviews with companies. Current information on AI and ML technologies will be used to identify integration opportunities that AI and ML can provide for supply chain risk management.

The remainder of this thesis will be structured as follows. Chapter 2 will give a background on AI, ML, and SCRM. In addition, the chapter will discuss the various supply chain risks faced by different industries. Chapter 3 will provide details on the methodology of this research project. Chapter 4 will provide an analysis of the research findings and interview results on the current practices used in various industries for analyzing, identifying, and managing risks. The chapter will also provide an analysis of best-in-class AI and ML tools currently available or emerging and companies that may provide these solutions. Chapter 5 will conclude with

recommendations on implementing best-in-class tools and methods, discussed in Chapter 4, to benefit the private sector in regards to SCRM.

Chapter 2

Background

As companies expand their supply chains to provide their services to more customers, or to reach global markets, they are increasing their supply chain risks. Customers' demand for faster delivery of products and better services puts a strain on an organizations' supply chain. Reaching global markets leads to political, financial, reputational supply chain risks. According to Global Risk Intelligence, "Numerous industries are negatively affected by disruptions in their supply chains, including the aerospace, defense, security, manufacturing, and construction industries." (Zeisl, 2020). The increase in supply chain risks creates a need for SCRM strategies to address predictable and unpredictable risks. New technologies, such as AI and ML, introduced in supply chains provide competitive advantages for companies that use them efficiently. The introduction of AI and ML has given companies the opportunity to change or improve their SCRM processes. AI and ML can help organizations with supply chain risks by analyzing large data sets with algorithms. By making sense of large data and generating new insights, supply chain leaders can make better decisions and prevent risks. The rest of this chapter will discuss SCRM, the top risks faced by the interviewed companies, AI, ML, and the definitions used in this thesis.

Supply Chain Risk Management

In recent years, the supply chain has become broader and more complex for many organizations. The focus is no longer on just Tier 1 suppliers but also on sub-tier suppliers. Different parts of the supply chain come into contact with different cultures and conditions,

especially in a global context. There is constant pressure to improve supply chain efficiency, reduce inventory, decrease lead times, reduce costs, etc. The pressure placed on supply chains, in addition to its scale, introduces many risks. This results in a need for SCRM. There are various methods to manage risks such as using excel, third party solutions, and manual analysis of past disruptions trends.

There are various definitions of SCRM, all are correct in their respective ways. One definition that covers both the objectives and stages of SCRM is as follows, “The identification, assessment, treatment, and monitoring of supply chain risks, with the aid of the internal implementation of tools, techniques and strategies and of external coordination and collaboration with supply chain members so as to reduce vulnerability and ensure continuity coupled with profitability, leading to competitive advantage” (Fan & Stevenson, 2018). This definition simply implies that SCRM is about identifying, assessing, mitigating, and monitoring risks with the help of internal and external forces. By addressing supply chain risks, companies can improve profitability, reduce supply chain vulnerabilities, and create competitive advantage.

In a 2015 report of Top 10 Supply Chain Disruptions by DHL, different industries and countries that have incurred substantial losses from various supply chain disruptions are listed

(DHL, 2016). Figure 1, below, shows the list of Top 10 Supply Chain Disruptions reported by DHL.



Figure 1. 2015 Top Supply Chain Disruptions (DHL, 2016)

This report was made available with data from DHL's Resilience360 platform, an SCRM software that uses technologies like AI and ML. The top disruptions in 2015 include port explosions, floods, strikes, goods held at the border, industrial actions, custom stoppages, canal congestions, category five hurricanes, and extreme winter weather (DHL, 2016). Another report

from DHL's Resilience360 platform lists the top 10 supply chain risk trends to watch for in 2019. Figure 2, below, shows the list of 10 top supply chain risk trends to monitor in 2019.



Figure 2. Top 10 Supply Chain Risk Trends in 2019 (DHL, 2019)

The top trends from the list were predicted with the Resilience360 platform based on the data it gathered on the 2018 supply chain risk landscape. According to DHL, seven key issues defined the supply chain risk landscape in 2018: (1) trade disputes, (2) supply chain cyber-attacks, (3) climate change, (4) port congestion, (5) high fuel prices, (6) cargo theft, and (7) industry zone

shutdowns (DHL, 2019). The Resilience360 platform predicted and identified issues that may impact supply chains in 2019. Some of these disruptions are unpredictable, meanwhile, others are predictable with the right data and tools. In many of these cases, the identification of possible risks would allow for contingency planning which would decrease the losses that companies may incur.

Natural disasters, such as earthquakes, tornadoes, hurricanes, and tsunamis, have damaged supply chains' production facilities, warehouses, distribution centers, and logistic networks. The earthquake and tsunami that occurred in 2011 in Japan led to a nuclear crisis that impacted Toyota's supply chain causing the closing of twelve plants which led to a profit loss of \$72 million per each day that the plants were not in operation. This unpredicted event damaged Toyota's production and led to a loss in output of at least 40,000 vehicles (Langeland, 2011). The use of SCRM solutions would have led to better decision making and contingency plans, preventing or reducing the profit loss. A minor disruption, for example, a fire in one production facility, may lead to a disruption in the entire supply chain.

The outbreak of Novel Coronavirus (COVID-19) has impacted many industries and their supply chains. Some interviewees of this research have also mentioned the impacts of the pandemic on their supply chain. At the point of the interviews, the impacts that were mentioned had to do with warehouses and suppliers that were located in China. Due to the shutdown in place and the virus spreading, workers at those locations were not able to work. Companies needed to find other suppliers and other methods to ensure the continuity of their supply chain. Due to social distancing requirements, labor-intensive processes in manufacturing are disrupted which may lead to short supplies of raw materials or products (Volkin, 2020). Other areas of the supply chain have also been affected by the pandemic. Goker Aydin, a professor at Johns

Hopkins Carey Business School, said that producers and distributors are facing demand for food, beverage, and cleaning products due to shoppers panic-buying in bulk (Volkin, 2020). The COVID-19 pandemic is an unpredictable disruption that is different from any other kind of supply chain disruption. For example, if a supplier was going bankrupt, a company can look for another supplier. But with COVID-19, everyone is affected.

Different industries, organizations, and segments of a supply chain face different types of supply chain risks. Many supply chain risks are common, such as inventory shortages or supplier delays, while others may be complex, such as natural disasters or economic issues. Companies that are impacted by the same natural disaster, such as a hurricane, will not face the same types of supply chain risks as their supply chains are different and will require different methods to mitigate or manage those risks. Every company encounter planned or unplanned risks such as IT and telecommunications disruptions, adverse weather, data breaches, and transportation network disruptions. Insurance firms that cater to businesses may need to assess the risks that their potential clients face before providing them with an insurance policy quote. Even after having provided a policy to a business client, the insurance firm may find that it is in their best interest to provide their clients with tools and methods to help identify and mitigate supply chain risks. Manufacturing companies need to identify supplier risks to better determine the reliability of their suppliers. Consumer goods companies may deal with transportation risks and disruptions caused by customer complaints or loss of revenue. Regardless of which industry a company operates in, there will be risks that they need to plan for in their supply chains. The military, for example, will need to analyze the various economic risks of a country, such as risks for corruption, disease, or ongoing conflict. Changes in laws and policies are also considered as a risk for industries. SCRM consists of four steps: identification, assessment, mitigation, and

control (Coelho Albertin, 2017). This thesis will focus on the use of AI and ML for identifying, assessing, and mitigating various supply chain risks.

Artificial Intelligence

Since 1950, AI has been a topic of research facing periods of low interest and periods of significant growth. Advancements in the information technology field, including the increase in computing power, has renewed interest in AI research starting in the early 2000s (Baryannis, Validi, Dani, & Antoniou, 2018). The resurgence of AI research has led to advances in fields that have not been explored before.

The definition of AI is continuously evolving, due to advancements in research, and applied differently depending on which industry and field it is used in. A dictionary definition from Merriam-Webster defines AI as (1) “a branch of computer science dealing with the simulation of intelligent behavior in computers and (2) “the capability of a machine to imitate intelligent human behavior.” (The Merriam-Webster Dictionary, n.d.). A simpler definition of AI is provided by Jeremy Achin, CEO of DataRobot, during his Japan AI Experience speech. Achin defines AI as “a computer system that is able to perform tasks that ordinarily require human intelligence” (DataRobot – Artificial Intelligence, n.d.). AI mimics the way a human behaves by having the ability to choose actions that lead to certain results and being able to do so in an uncertain environment. Many companies today have access to large amounts of data. AI systems provide these companies value from data by “automating and optimizing processes or producing actionable insights” (DataRobot – Artificial Intelligence, n.d.). The adoption of AI systems by companies results in a competitive advantage in the industry, higher profits, an increase in jobs,

and the ability to delegate resources to more value-added business processes. It should be noted that the term “AI systems” does not refer to AI as a system itself. Instead, AI is implemented or designed into a system to allow it to act intelligently.

Machine Learning

A subset of AI is ML, where algorithms are coded to “learn by example from historical data to predict outcomes and uncover patterns not easily spotted by humans” (DataRobot – Machine Learning, n.d.). ML learns from the information given and applies its knowledge, the algorithms coded into it, to uncover insights, relationships, and make predictions. AI systems powered by ML allows companies to gather insights from large amounts of data, enabling them to make better decisions (DataRobot – Machine Learning, n.d.). Supply chain leaders are often placed in situations where they are tasked to make optimal decisions. Although optimal decisions are not what ML offers, ML can efficiently analyze data to provide insights that can be used for decision making. The outcomes of the decision made are impacted by various factors that may be difficult or impossible to monitor and analyze in a timely manner. ML can be applied in these situations to accurately predict the future without constant human programming, enabling it to be used in different scenarios. For example, a supply chain leader may be able to use the predictions and results generated with ML to make smarter decisions.

Difference between AI and ML

AI and ML, although the terms are sometimes used interchangeably, are not the same. As stated above, ML is a subset, or application, of AI. On one hand, AI learns by acquiring

knowledge and learning how to apply it, on the other hand, ML learns knowledge or skills by relying on big data sets and experience (Parthasarathy, 2019). AI focuses on the increase in chances of success in finding optimal solutions. ML focuses on the increase in accuracy rather than success (Parthasarathy, 2019). Simply put, AI is about decision making while ML is about gaining knowledge from data.

An example, that highlights the difference between AI and ML, could be the application of these two technologies to make decisions for the logistics department of a company. If a supply chain manager is tasked to find the best route for delivering inventory from a distribution center to a customer manually, it would take a lot of time to find and analyze the fastest and shortest routes. However, if the supply chain manager decides to use a system with AI, the system would track and analyze all the possible routes and consider other factors that may affect travel time. The system would also be continuously updating to consider changing factors, such as weather conditions or roadblocks, in its solution. AI would not learn from the data it acquires to make a better analysis. Instead, it makes decisions and learns from the outputs of the decisions, that are feed to it as data, to improve future decisions. This is similar to humans learning from past decisions that they have made. If the manager decides to use ML, the system would require data on possible routes and the changing factors. The system would provide the fastest and shortest routes after analyzing the data. Any changing conditions, such as traffic, would not be considered unless the data is provided continuously to the system. ML learns from the data given to it and provides knowledge, such as trends in the data. This example highlights the differences between AI and ML. It is important to understand that since ML is a subset of AI, systems that use ML are essentially using AI which teaches the machine to analyze datasets and learn from them.

Definitions

For this thesis, the following definitions are used for AI, ML, and SCRM. The definitions are derived from the findings reported in the above sections.

1. Supply Chain Risk Management: The identification, assessment, treatment, and monitoring of supply chain risks, with the aid of the internal implementation of tools, techniques and strategies and of external coordination and collaboration with supply chain members to reduce vulnerability and ensure continuity coupled with profitability, leading to competitive advantage.
2. Artificial Intelligence: Systems that solve cognitive problems by mimicking human behavior. AI focuses on decision making where it seeks an optimal solution and can sense, reason, act, and adapt.
3. Machine Learning: An application of AI, uses large data sets to learn and improve from experience without being explicitly programmed. ML focuses on finding trends, where it finds hidden patterns to improve the accuracy of predictions.

Chapter 3

Methodology

This thesis consists of information gathered from various publicly available sources such as articles, websites, scholarly journals, and industry reports. Several sources are looked at to develop the definitions of SCRM, AI, and ML. The majority of the information gathered from these sources is used in the background section of this thesis. The search context of this paper consists of keywords such as “supply chain risk management, or supply chain risks, or AI in the supply chain, or AI for supply chain risk, or supply chain disruptions, or identifying supply chain risks, or AI/ML tools for supply chain risks,” just to name a few.

The analysis portion of this thesis (Chapter 4) mainly consists of data gathered from the interviews. Findings from publicly available sources are also included in the analysis to supplement areas where interview findings were not sufficient. The following section discusses the methodology for conducting the interviews for this research.

Interviews

To better understand the current situation of how AI and ML impact different companies, interviews were conducted with companies in various industries. The interview is structured as a thirty-minute discussion about the impacts of AI and ML in identifying and managing supply chain risks and the top risks that companies face. The interview also provides a means to identify the current companies or tools that supply AI and ML technologies and solutions for SCRM.

The interview guide used during the discussions is shown in Appendix A. The first page of the interview guide is the one provided to the interviewees, which defines the terms SCRM,

AI, and ML and also the outline of the discussion. The second page is the internal guide that consists of three categories of questions.

The first few questions of the interview are developed to understand the role of the interviewee in their organization. This information is confidential and will not be provided in this thesis. The purpose of understanding the interviewee's role is to provide a more detailed view of their knowledge of AI and ML technologies and solutions. Interview participants may or may not have a technical background, understanding this information allows for the rest of the interview questions to be structured to their point of view of AI and ML. This section also gathers information on the supply chain risks that are of the highest priority to the segment of the supply chain that they are in.

The second category of questions aims to understand what tools and methods are currently implemented in the organizations and what tools they are lacking. The purpose of this section is to gain a better understanding of what supply chain risks are of higher priority to the organization and what tools are currently used to manage those risks. This provides information on where the organization is at in terms of integrating AI and ML tools into their risk managing processes. Some organizations may just be researching and experimenting with AI and ML, while others may have already implemented these tools. This leads to the next section.

The third category of questions focuses on the areas of supply chain risks that AI and ML can help improve and the process for implementing these tools. It is important to understand how the use of AI and ML tools or solutions impacted the organization and whether the results were positive or negative. This section provides a foundation for why an organization is using AI and ML tools to reduce risks and whether an organization is using tools developed by external

vendors or their IT department. The output of this third category of questions is a list of AI and ML tools and solutions currently on the market.

The questions in the interview guide are not meant to be asked in any type of order. Depending on the role of the person interviewed, the type of tools currently used for SCRM, and the level of involvement with AI and ML tools, some questions may be irrelevant and repetitive. Additional questions are then asked that are not on the interview guide, this allows for more valuable information from the interviews. The main purpose of the interview is to provide an understanding of the industries that are looking into AI and ML technologies, the organizations that are currently using AI and ML tools, and what risks are being targeted with these tools.

Chapter 4

Analysis

Different sectors require and adopt different technologies for managing supply chain risk. Implementation of AI and ML tools and solutions may not be the optimal choice for certain companies. This chapter will discuss the research and interview findings and the AI and ML tools and solutions available. To protect the confidentiality of the interviewed companies, the company names will not be mentioned. Table 1 shows the industries that the companies operate in and supply chain perspectives of interviewees.

Table 1. List of Interviewed Companies

Company	Industry	Supply Chain Perspective
A	Business Insurance	Supply Chain Business Resilience, Risk Services
B	Heavy Equipment	Supplier Risk
C	Pharmaceuticals & Consumer Products	Manufacturing & Procurement Risk
D	Medical Equipment & Devices	Supplier Risk
E	Business Services	Supply Chain Research and Development
F	Pharmaceuticals	Global Supply Chain Risks
G	Household Products	Manufacturing Risks
H	Computer Hardware	Global Supply Chain Risks
I	Air Courier	Supplier Risks
J	Diversified Chemicals	Supplier Risks, Global Supply Chain Risks
K	Integrated Freight and Logistics	Data Science & Machine Learning

There are different perspectives on AI, ML, and SCRM provided in this analysis. The interviewees consist of those who are part of the global operations, logistics, procurement, sourcing, supply chain operations, supply chain research and development, supply chain risk, supply chain resilience, or supplier risk management department. Some interviewees have more

knowledge of AI and ML while others may not know as much. Figure 3, below shows the diverse range of knowledge the interviewees have on AI and ML.

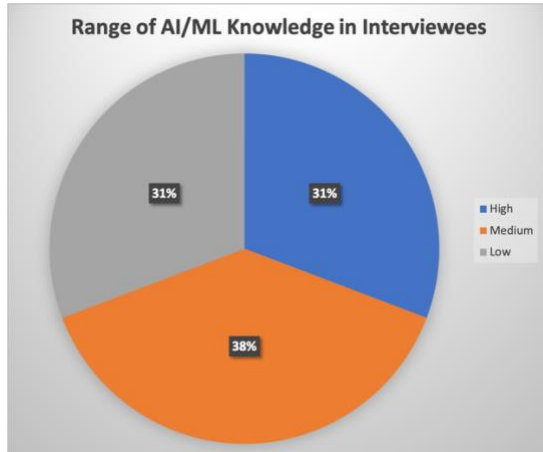


Figure 3. Range of AI/ML Knowledge in Interviewees

Different supply chain departments in a company may have different levels of AI or ML implementation, varying from no implementation or research on this topic to high levels of implementation or research.

Supply Chain Risk Findings

This section will discuss the top supply chain risks and technologies mentioned during the interviews. The interview findings present both external and internal supply chain risks. External supply chain risks include demand and supply risks, epidemic risks, natural disaster and weather risks, political risks, and supplier risk. Internal supply chain risks include information technology, infrastructure, manufacturing, mitigation and contingency, and workforce risks. Figure 4, below, shows the list of supply chain risks gathered from the interviews.



Figure 4. External and Internal Risks Findings

Currently, more attention has been placed on adverse weather disruptions, cyber-attacks and data breaches, tier 2 and beyond supplier disruptions, and unplanned for IT and telecommunications disruptions. Almost every interviewee mentioned supply chain risks related to weather-related events and their impact on their transportation network. Events like winter storms may strongly impact demand and supply risks, infrastructure risks, and transportation risks. Every company interviewed have contingency plans in place for these types of disruptions. Supplier risks was another hot topic of discussion during the interviews. The main focuses were on the financial health, performance, and compliance of suppliers. Information Technology (IT) risks were mentioned by a few companies, this may be due to the different levels of expertise interviewees had on IT operations and processes. Cyber-attacks, data breaches, and telecommunication outages have a high impact on the performance of an organizations' supply chain and those of its suppliers.

The top risks reported by Resilience360 for 2020 include the threat of cyber-attacks, changes in trade policy, increased economic sanctions, protests and strikes, border delays, climate activism, new environmental regulations, territorial disputes due to new trade routes, narcotic smuggling in container ships, and black swan events (Britt, 2020). Black swan events are events that are seemingly impossible to predict and are responsible for long-lasting supply chain disruptions, such as COVID-19 which has impacted everyone (Britt, 2020). The majority of the companies interviewed have seen disruptions in their supply chains due to the COVID-19 global pandemic. Many companies reported that the shutdown in Wuhan, China has stopped some of their plants that are operating in that location. Company D mentioned that due to COVID-19, they have been receiving requests to do business with suppliers and companies that normally would not consider doing business with them. Company C mentioned that most of their products are sourced from one supplier and if that one supplier goes down, they will need to find a new supplier. The COVID-19 pandemic has forced companies to reevaluate who they work with.

The COVID-19 pandemic is also requiring companies to clean up their data. As contingency plans are put in place, many functions and processes are reevaluated. Company C discussed the issue that they have with data, such as duplication or inaccurate data. Due to each function working as silos, data is not able to be shared between functions without the right format. For Company C, cleaning up their data was not a high priority until COVID-19. It is only after the disruption happened that their company has increased the priority of having accurate data.

During the interview, Company A has mentioned that the automotive industry is impacted by the Just In Time (JIT) and Just In Sequence (JIS) inventory requirements. These

requirements create many supply chain risks for the automotive industry such as supplier risks, transportation risks, and infrastructure risks. A delayed shipment may be a risk that would impact JIT and JIS requirements. Any disruption to the supply chain will impact its ability to provide JIT or JIS services. COVID-19 has also had a significant impact on suppliers who operate under JIT or JIS requirements. These suppliers may not be able to absorb the shock of the pandemic. JIT or JIS requirements may be a downfall for organizations that are not planning for risks or prepared for risks.

Unplanned IT risks can negatively impact an organization's supply chain. Depending on where an IT outage or cyber-attack occurred, different segments of supply chains may be impacted. Company C discussed the effects of an unplanned IT or telecommunications outbreak on its supply chain. Depending on the severity of the outbreak, a company may see disruptions in its basic way of working or lost a worksite for a certain duration of time. Suppliers of a company that are affected by an IT or telecommunications outbreak may also impact the company sourcing from it. Company J mentioned that cyber-attacks that happen to them or their suppliers will have an impact on their supply chain. If suppliers have a cyber-attack it will impact their ability to provide services to their customers.

SCRM Methods and Technologies

Many companies rely on different technologies to predict, identify, record, monitor, and measure supply chain risks. The current technologies used by the companies interviewed are shown in the list below, Figure 5.

SCRM Technologies	Excel Spreadsheets
	Simulations
	Artificial Intelligence and Machine Learning
	Third-party Solutions
	Blockchain
	Big Data Analysis
	Internet of Things
	Predictive Modeling Programs
	Geopolitical and Geospatial Models
	Business Continuity Management Software

Figure 5. SCRM Technologies

The level of technology usage for SCRM varies depending on the organization's core competency. For example, Company G mentions that the use of technology is not part of their core competency, while Company K invests heavily in the use of technology for SCRM. Besides using technology to manage supply chain risks, some companies are using more traditional and manual methods, such as Excel spreadsheets. Company C conducts conversation-based risk assessments to uncover areas of exposure with its suppliers. The data gathered from these proactive conversations are later stored in a software that acts as a depository. Company E mentions that a lot of their supply chain risk analysis is done manually. They use spreadsheets to track past weather events by having an employee manually keep track of demand variability during those events. Their focus is more on post-mortem analysis. More detail is discussed in the next section, Artificial Intelligence, and Machine Learning Findings

The use of manual methods to track risks is prone to errors and takes longer compared to using more automated methods. Company B is beginning to focus on predictive analysis to help predict when their suppliers are going to miss shipments, the switch from manual processes to using predictive analysis will help them cut down on the time and resources needed to identify problematic suppliers. Many other companies have also mentioned that they would want to use

predictive AI solutions to help them better identify and predict supply chain risks. A chart is shown in the next section to show the level of involvement the interviewed companies have with AI and ML.

Artificial Intelligence and Machine Learning Findings

The majority of the companies interviewed are researching and implementing AI and ML tools and solutions for SCRM. Some companies have not started implementing AI solutions, but are currently in the process of reviewing available options in the market. Figure 6, below, shows the level of involvement with AI and ML technologies of the companies interviewed. The chart summarizes the response from interviewees when asked about the usage of AI and ML for SCRM.

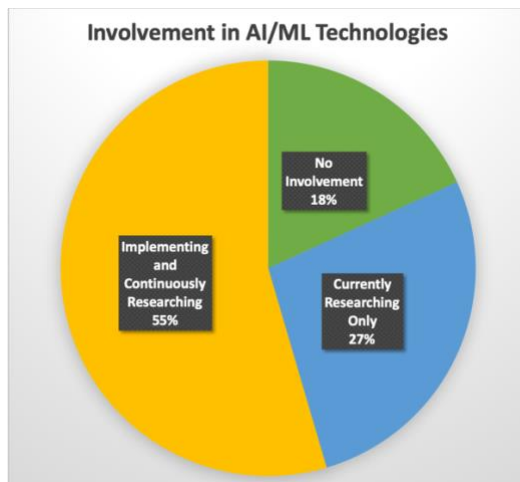


Figure 6. Involvement in AI/ML Technologies

Those with no involvement in AI and ML technologies are still using manual methods to track risks, such as looking through data on past disruptions or past trends and analyzing manually and using other software, such as Predictive Modeling Programs or Business Continuity Management Software. Twenty-five percent of participants are currently researching

AI and ML solutions that may benefit their supply chain. The remaining fifty-five percent are implementing or have implemented AI and ML tools and solutions. They are also continuously researching and assessing other supply chain risk processes that may benefit from the implementation of AI and ML tools.

The decision to build AI and ML technologies inhouse, outsource, and/or purchase these technologies from external vendors varies from company to company. Figure 7, below, shows the advantages and disadvantages of building AI and ML in-house, outsourcing, or purchasing from external vendors.

AI/ML Implementation: Advantages & Disadvantages

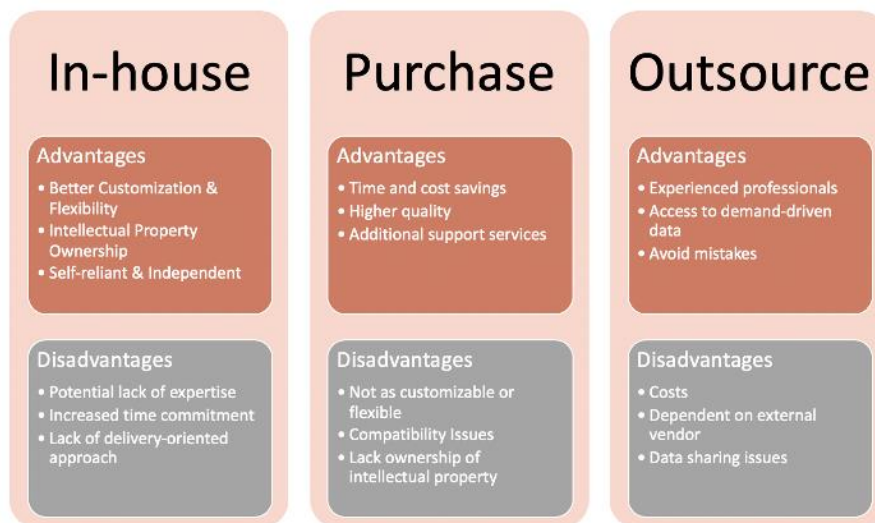


Figure 7. AI/ML Implementation: Advantages & Disadvantages

Implementing an AI solution for SCRM can be challenging but can also provide a competitive advantage. There are three options to choose from when deciding how to implement AI and ML solutions: building solutions in-house, purchasing a ready to use solution, or outsourcing to external vendors (Haponik, 2019). Depending on the company, it may be beneficial to build solutions in-house for some business process and outsource the rest to external AI partners. Before implementing AI or ML, companies should evaluate their supply chain and

business structure. An implementation project should add value to the business and be aligned with supply chain processes.

Figure 8, below, shows which implementation methods were used by the companies that were interviewed.

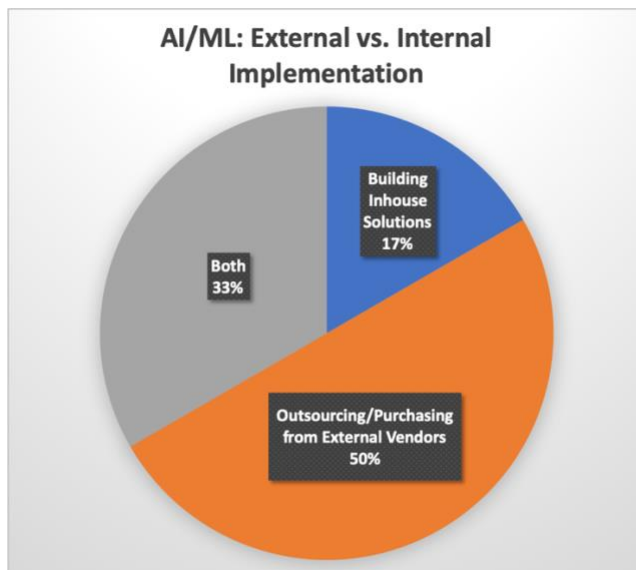


Figure 8. External vs. Internal Implementation Methods

Of the fifty-five percent of companies that are implementing and continuously researching AI and ML technologies, fifty percent are using external vendors to supply their AI and ML needs. Thirty-three percent are building in-house solutions and using external vendors. The remaining seventeen percent are only building these technologies and solutions internally. The data collected for this figure is limited to the perspective and knowledge of the interviewees. This means that if the interviewee was part of the North America team in a global supply chain, they may not have insight into what methods were used by other supply chain risk leaders.

AI/ML Tools

This section discusses the AI and ML tools and solutions available on the market for managing supply chain risks. The AI and ML tools researched may provide solutions specifically for supply chain risks or solutions for other supply chain aspects that may potentially be a risk. Table 2, below, lists the tools and solutions, the company that provides it, and the description of the tool. This is not a complete list, as many companies are starting to provide solutions with AI and ML technologies that may not be easily found. The following list is found through online research and the information provided by interviewees.

Table 2. AI/ML Tools on the Market

Company	Tool/Solution	Description
AlphaSense	AlphaSense	Provides real-time insights into companies and topics impacting your industry
BitSight	Critical National Infrastructure	Measure, monitor and investigate sovereign cybersecurity risks across industry sectors and key critical infrastructure companies
Bristlecone Labs	Sense.ai	End-to-end visibility of supply chain, foresee risks and formulate methods to prevent risk and build business resilience
	Trace.ai	Monitor and track shipments, optimize logistics and transportation
	Demand.ai	External and Market insights triangulated with forecast and order data, improve forecast accuracy with reliable indicators of demand
DHL – Resilience360	Supply Watch	Advanced early-monitoring system to mitigate supplier financial, stability, and compliance risks
	Risk Assessment	Maps every node in the supply chain and allows companies to evaluate the risk level at each node to increase resilience and provide options for immediate recovery
	Supply Chain Visualization	Provides the earliest possible notice of potentially disruptive incidents with an easy to comprehend view of the supply chain
	Transparency Portal	Builds a comprehensive picture of the multi-tier supply network, helps avoid brand and reputational loss, ensure supplier compliance, and build a resilient supply chain
GeoQuant	GeoQuant	AI-driven political risk intelligence platform that measures, analyzes and forecasts political risks in real-time

IBM	IBM Sterling – Supply Chain Insights with Watson	Predict, assess, and mitigate disruptions and risks with AI-powered capabilities to optimize supply chain performance
LexisNexis Risk Solutions	Risk Management Solutions	Search, monitor, score, and investigate consumers and businesses quickly
Llamasoft	Llama.ai platform	Provides digital representation of end-to-end supply chain, predict, assess, and understand risks, evaluate trade-off to speed or automate decisions
MetricStream	Supplier Risk and Performance Management	Supplier Risk and Performance Management solution built on its Governance, Risk, and Compliance (GRC) platform
O9 Solutions	O9 platform	A single platform that takes into consideration risks for demand, supply, and business planning with the use of AI/ML technologies, focused on forward visibility by helping companies plan ahead with ease
Resilinc	EventWatch	Monitor for anything that can impact supply chain 24/7 globally
	RiskShield	Proactively identify, mitigate, and quantify risk at the supplier level, product level, parts level, and sub-tiers
	Multi-Tier Mapping	Map supply chain across all tiers to gain visibility and improve transparency
RiskLogik	RiskLogik (Supply Chain Resilience solution)	Provides a comprehensive picture of supply chain and disruption chain vulnerabilities and ways to mitigate risks
	CyberLogik	Cyber risk identification and management platform that is fully integrated with RiskLogik
Riskmethods	Risk Radar	Profiles and monitors the supply chain network to identify risks in real-time
	Impact Analyzer	Helps minimize the business impact of risk by assessing supplier criticality and detecting vulnerabilities at the category level
Riskpulse	Sunrise	Detect and analyze risks that could impact shipments and automates the task of finding lower-risk alternatives, looks at weather-related risks, transportation nodes, and infrastructure risks
	OnTime	Calculates the probability of shipments being early, late, or within a specific time frame and returns top risk reasons for potential missed delivery time
	InFull	Identify shipments that may be compromised and ensures cargo is within quality thresholds
	OverSee	Calculates risks due to external factors and provides risks scores for physical assets across three categories: environmental, social, and infrastructure
Scoutbee	Artimis (Streamline and DeepSee)	Two features powered by Artimis: (1) Streamline digitalizes supplier sourcing, identification, and onboarding, (2) DeepSee unifies supplier data and provides a holistic view of suppliers

	Impact Analyzer		x	x							
RiskPulse	Sunrise				x	x					
	OnTime				x						
	InFull			x	x						
	OverSee					x	x				
Scoutbee	Artimis (Streamline and DeepSee)		x								
Solvovo	Solvovo platform				x					x	
Sumo Logic	Sumo Logic platform							x			

Interview participants also mentioned potential AI and ML solutions that they would like to see on the market or build inhouse. Figure 9, below, shows a list of potential AI and ML solutions that interviewees would like to see in the future.

Potential Uses of AI/ML Technologies

Holistic view of upstream and downstream supply chain risks
Logistics – selection of carriers and best transportation routes
Prediction of risks related to suppliers for better risk assessment conversations
Merge data from other external vendors with company data to provide actionable insight on risks
Inbound and outbound freight damage risks by tracking related issues and producing mitigation techniques
One platform for SCRM, identifying, predicting, analysis, and monitoring all supply chain related risks
Strengthen demand forecasting
Potential scenarios, simulations of impacts of supply chain disruption before occurrence
Predictive analysis for maintenance of equipment in a factory

Figure 9. Potential Uses of AI/ML Technologies

The suggestions of potential uses seem to be more focused on aspects that can improve current SCRM processes. Several companies believe that if AI and ML can create simulations of best-case and worst-case scenarios of disruption and the results of the implementation of contingency plans it would greatly help them make better supply chain decisions. However, due to supply chain risk and technological investments not being the highest priority at some organizations, the implementation of AI and ML technologies for SCRM is hindered. There are other reasons why companies are not implementing AI and ML solutions, such as costs and lack of talent or experts in that field.

AI/ML Drawbacks

The research available on AI and ML for SCRM is limited regarding the drawbacks of using such technologies. There are, however, many sources that mention the drawbacks of implementing AI in supply chain management, not specifically in SCRM. The findings are compiled in Table 4, below.

Table 4. AI/ML Drawbacks

Drawback	Description
High Costs	Initial investments for implementing an AI/ML solution may be costly. Organizations that have no experience with implementing AI/ML technologies may need expert advice, incurring additional costs.
Replace Jobs	Employees may deter from the proposal of AI/ML implementation as they fear the technology may replace their jobs (Reuters, 2018). Without the support of employees, implementation projects will likely fail. Organizations should keep employees in the loop and notify them of changes to business processes.
Data Issues	Most AI/ML solutions require a large data set from the company to function. If a company does not have accurate data it will be reflected in the results (Reuters, 2018). Companies that have supply chain silos will likely have difficulty sharing data and have duplicate and inaccurate data. Such companies may have difficulty implementing AI technologies for the entire supply chain, which will limit them from having visibility of risks for the entire supply chain.
Security Issues	AI/ML solutions may use sensitive company information. Because of the maturity of AI/ML technologies, organizations may encounter security risks without the right tools and processes to secure their data.
Limited AI experts	Implementation of AI/ML tools will require expert knowledge of how AI/ML works and how it can be aligned with business values and processes (Robinson, 2019). Companies may need to invest heavily in training employees to use AI/ML-powered solutions. Limited knowledge on the topic may deter organizations from building solutions in-house. Without the necessary skills, an incorrect algorithm will generate more incorrect algorithms that may be costly for the organization.
Limited Solutions on Market	Based on the research findings, there are limited AI/ML tools and solutions available on the market for SCRM. Organizations may have difficulty finding a solution that best matches their need. Many startups that offer AI/ML solutions may not be mature enough for some companies' needs.
Alignment with Existing Processes and Systems	The implementation of any software or system, not just AI/ML, will require organizations to analyze how it aligns with their existing processes and systems. If a company's legacy systems do not support AI/ML solutions, there may be a need to reevaluate how implementation will proceed.

The interview findings for companies that are still researching AI or do not plan on implementing AI show many reasons as to why they are hesitant in implementing AI and ML tools and solutions. One of the reasons for choosing not to implement AI was due to the structure of the company and how data is compiled and shared. Company C mentioned that their company is decentralized, which is a barrier to implementing AI and ML technologies. Different functions inside their organization work independently, meaning there may be duplicates of the same data, inaccurate data, and difficulty sharing data between functions. Another reason is that technology investments are not a priority for the organization. Company G mentions because of the structure of their organization and their values, they do not have a strong focus on technological innovations. Many companies are still researching AI and ML. Due to the maturity of the technology, many companies are unsure if the technology will be aligned with their more mature processes. Although there may be drawbacks of implementing AI and ML solutions, organizations will also be able to benefit that AI and ML can bring when managing their supply chain risks. The key is to research AI and ML technologies to see which is the best match for the organization, by doing so will prevent errors in the process that may decrease efficiency when the goal is to increase efficiency.

Chapter 5

Conclusion/Recommendations

Investing in AI and ML tools and solutions for SCRM can help organizations avoid costs, gain competitive advantage, improve supply chain processes, maintain business continuity, and promote efficiency in the supply chain. Advancements in AI and ML and the emergence of startups that provide these solutions create opportunities for companies who are looking to better manage supply chain risks. Many of the companies interviewed have reported that they are currently using AI and ML solutions. The remainder of the companies are either still researching these technologies or are not focused on implementing specifically AI and ML solutions.

Implementation of AI and ML without research and analyzing how they will benefit supply chain risk decisions may lead to undesirable consequences. As such, companies need to have a clear understanding of their existing supply chain processes and systems. Organizations can then decide whether it is better to build solutions in-house, outsource, or purchase from external vendors. If purchasing from external vendors, organizations should determine if the solution, without customization, will be aligned with existing supply chain processes. It is recommended that organizations assess their current data structures within their organization before implementing AI and ML.

As there are different available AI and ML tools and solutions available on the market, organizations should proceed with caution before deciding which to use. The focus of implementing AI and ML should not be for a return on investment, instead, it should be focused on improving existing processes and reducing risks in the supply. AI and ML should be used to

tackle risks that are difficult to analyze manually and to identify risks using large data sets that were not identifiable using manual methods. Different AI and ML tools and solutions can tackle different risk factors. For example, if a company is having issues with single or sole-source suppliers for a product, using a solution that is focused on identifying supplier risks may be the best solution. If a company operates within a global context and come in contact with many political risks, an AI-based software for identifying, forecasting, and analyzing global political risks in real-time may be useful. It is recommended that organizations identify supply chain risk areas that have the highest impact and probability of occurring. By doing so will narrow down the search for AI and ML tools and solutions.

As more AI and ML research becomes available and technological innovations are being developed, there may be an increase of AI and ML technologies available in the market for SCRM. The increasing attention on SCRM will also increase the demand for more innovative solutions to manage risks. The benefits of AI and ML technologies for SCRM will generate long-term benefits for organizations that adopt these solutions. Based on the research findings, it is concluded that AI and ML are most suitable for identifying and assessing supply chain risks.

Appendix A

Interview Guide

Penn State Honors Thesis – SCRM Practitioner Interviews

Application of Artificial Intelligence and Machine Learning to Supply Chain Risk Management

Purpose and Background

I am a senior at Penn State working on my undergraduate thesis. As part of my research, I am conducting interviews with supply chain risk management (SCRM) practitioners. The purpose of these discussions is to gather information on supply chain risk management activities and to discuss the current and future use of artificial intelligence (AI) and machine learning (ML) tools to managed supply chain risks.

For this thesis, I am using the following definitions:

Supply Chain Risk Management: The identification, assessment, treatment, and monitoring of supply chain risks, with the aid of the internal implementation of tools, techniques and strategies and of external coordination and collaboration with supply chain members to reduce vulnerability and ensure continuity coupled with profitability, leading to competitive advantage.

Artificial Intelligence: Systems that solve cognitive problems by mimicking human behavior. Artificial Intelligence (AI) *focuses on decision making* where it seeks an optimal solution and can sense, reason, act, and adapt (e.g., improving supply chain optimizations decisions).

Machine Learning: An application of AI, uses large data sets *to learn and improve from experience* without being explicitly programmed. Machine Learning (ML) focuses on finding trends. ML finds hidden patterns to improve the accuracy of predictions (e.g., improving demand forecasts by looking for trends in large data sets).

Discussion Topics

I would like to speak with you about the discussion topics below. I am asking for approximately 30-60 minutes of your time.

1. SCRM Background
 - a. Roles and responsibilities
 - b. Key supply chain risks
 - c. Risk prioritization
2. SCRM tools
 - a. Tools currently used to manage risks and the risks addressed by those tools
 - b. Decision to implement tools
 - c. Additional technology/tools that are needed
 - d. Implementation challenges
 - e. Outcomes of SCRM tool implementations
3. Use/potential use of AI/ML
 - a. Current/planned use of AI/ML tools
 - b. Elements of SCRM (e.g., identification, analyzing, managing, and controlling) and types of risks (e.g., supplier, product, infrastructure, transportation, cyber) that AI/ML can best be applied
 - c. Outcomes/potential benefits of AI/ML tool implementation

Appendix B

Interview Guide (Internal Version)

Application of Artificial Intelligence and Machine Learning to Supply Chain Risk Management Interview Guide (Internal)

1. SCRM Background (*Goal: Gain an understanding of the organization and their highest priority supply chain risks*)
 - a. What is your role in the organization with regards to SCRM?
 - b. What are the top supply chain risks that your organization faces?
 - c. How do you prioritize supply chain risks?

2. SCRM Tools (*Goal: Document what SCRM tools are used today and what the current tools are lacking?*)
 - a. What tools do you use to manage risks in the supply chain?
 - If no tools are used, how are risks managed?
 - If SCRM tools are used, what tools and what types of risks are being addressed with the tools? Is there a different tool or software for each risk?
 - b. For the tools that are currently used to manage supply chain risks, what was the decision that made you choose that tool compared to all the other tools available in the market?
 - c. What supply chain risks could benefit from additional technology/tool implementations that would improve your supply chain operations? (i.e., what tools are lacking that could improve supply chain risk management?)
 - d. What was the biggest challenge that needed to be overcome to implement your SCRM tools?
 - e. How has the implementation of SCRM tools improved supply chain risk decision-making?
 - Can you provide some examples of how the tools have changed an SCRM decision?

3. Potential/current use of AI/machine learning (*note: refer interviewee back to AI/ML definitions*) (*Goal: Identify what areas of risk AI/ML can help improve*)
 - a. Have you used or considered AI/ML tools to manage supply chain risks?
 - What AI or ML tools are used? How was AI/ML employed? Did you have any implementation challenges?
 - If AI/ML is used, how have you used AI/ML tools to manage supply chain risks?
 - b. Which SCRM element or risk area has the most potential for AI/ML to assist?
 - There are different elements of SCRM (e.g., identification, analyzing, managing, controlling)
 - There are different types of risks (e.g., supplier, product, infrastructure, transportation, cyber); Which elements are AI/machine learning used or planned to be used for?
 - c. How do you think that the implementation of AI/machine learning tools has improved (or will improve) risk predictions and the management of supply chain risks in general?

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ACADEMIC VITA

Tina Pan

EDUCATION

The Pennsylvania State University || Schreyer Honors College

Smeal College of Business

Bachelor of Science in Supply Chain and Information Systems

College of Information Sciences and Technology

Bachelor of Science in Information Sciences and Technology

Integration and Application Option

University Park, PA

Spring 2020

RELEVANT EXPERIENCE

Schreyer Honors College

Thesis Research: AI/ML in SCRM

University Park, PA

August 2018– May 2020

- Conducted comprehensive research on the impacts of Artificial Intelligence and Machine Learning in Supply Chain Risk Management
- Communicated directly with Supply Chain Leaders to gather data on managing risk with AI/ML
- Analyzed AI/ML tools and solutions and its correlation with various types of supply chain risks using Excel
- Utilized findings to prepare charts and tables for the thesis

Armada Honors Project: On-Time Performance

- Analyzed the dock scheduling tool at the warehouse to determine efficiency of the tool
- Generated tables showing findings from analyzing docking data
- Provided insights and recommendations through a presentation

Dell Honors Project: Production Efficiency in Finished Goods Warehouse

- Discussed technologies feasible for promoting production efficiency in the warehouse
- Visited warehouse to gain a better understanding of the processes in place and which processes should be replaced
- Conducted weekly meetings with Dell representatives to discuss findings
- Analyzed possible solutions and compiled results into PowerPoint Presentation

Mount Nittany Health

Information Services Intern

State College, PA

April 2019 – October 2019

- Completed daily training modules for the new Electronic Medical Record System to be able to provide assistance to doctors and nurses during and after Go-Live week
- Influenced the development of the system by providing feedback on different components of the EMR system
- Maintained accurate patient data by transferring/updating data from old system to new system

LEADERSHIP EXPERIENCE

Penn State Volunteer Income Tax Assistance

President, Volunteer

University Park, PA

August 2018 – May 2020

- Completed trainings to understand income tax laws and preparation procedures; passed examinations to assist low-income earners file taxes
- Conducted meetings with E-board members to recruit volunteers and provide additional training sessions
- Engaged in conversations with tax filers and provided assistance for any concerns or questions

Penn State APICS

President

University Park, PA

January 2019 – December 2019

- Directed a diverse team in organizing events and networking sessions for Supply Chain Students
- Promoted APICS membership and case competition to Smeal Students

ADDITIONAL EXPERIENCE/HONORS/SKILLS/INTERESTS

IST Student Government – Treasurer and Merchandise Chair

Conversational in Mandarin Chinese

Skills: Intermediate with Microsoft Word, Excel, and PowerPoint, familiar with Precision Tree, @Risk, Java, and MySQL